ACIDIC PRECIPITATION IN ONTARIO STUDY

ANNUAL PROGRAM REPORT

FISCAL YEAR 1985/1986

APIOS REPORT NO. 008

A.P.I.O.S. COORDINATION OFFICE

ONTARIO MINISTRY OF THE ENVIRONMENT

DECEMBER 1986

PROGRAM COORDINATOR: G. W. SCOTT

PREFACE

The Acidic Precipitation in Ontario Study was established in 1979. This multidisciplinary program is managed by the APIOS Coordination Office which:

- provides overall leadership and conducts the budget preparation and management for the program;
- provides secretarial support for the technical committees thus facilitating the transfer of information among working groups;
- maintains a library of current information on acid rain;
- responds to public enquiries for information and coordinates responses when more than one Branch is involved;
- maintains coordination links with major studies in other provinces and countries;

Additional information concerning any of the activities described in this report may be obtained by contacting that Office at the following address:

APIOS Coordination Office
7th Floor
40 St. Clair Avenue West
Toronto, Ontario

(416) 323-5051

Mailing Address:

APIOS Coordination Office
Ministry of the Environment
Suite 100
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

(Un version abrégée est disponible en français)

TABLE OF CONTENTS

Page

INTRODUCTION 1

TASK #1 - ATMOSPHERIC PROCESSES STUDIES 3

A. Emissions Inventory 3

B. Modelling and Meteorology Studies 3
i) Atmospheric Modelling 3
ii) Meteorological Data Acquisition System 4

C. Deposition Monitoring Networks 5

D. Oxidants Strategy Development 5

E. Laboratory Support and Quality Assurance ... 6

TASK #2 - AQUATIC EFFECTS STUDIES 7

DORSET SITE DEVELOPMENT 7
A. Chemical Studies 7
i) Calibrated Watersheds 7
a) Chemical Limnology 7
b) Lake and Stream Models 8
c) Metal Contaminants 8
ii) Extensive Lake Sampling 8

B. Biological Studies 9
i) Algae 9
a) Filamentous Algae 9
b) Odour Production by *Chrysochromulina breviturrita* 10
c) pH Change and Algal "Fossils" in Lake Sediments 10
ii) Zooplankton 11
iii) Invertebrates 11
iv) Fish 11
a) Laboratory Studies 11
Acute Toxicity 11
Chronic Toxicity 12
b) Field Studies 12
Comparative Lakes Projects 12
Studies of Fish Kills on Plastic Lake 12
Trend Through Time Studies 13
Mercury Uptake 14
v) Wildlife Studies 14

D. Remedial Methodologies Development 15

E. Laboratory Support and Quality Assurance ... 16

TABLE OF CONTENTS (continued)

Page

TASK #3 - TERRESTRIAL EFFECTS STUDIES 18

A. Vegetation Studies 18
i) Lichen and Bryophyte Study 18
ii) Vegetation Studies - Mobile Rain Exclusion Canopies 18
iii) Vegetation Studies - Greenhouse Experiments 19

B. Soil Studies 20
i) Baseline Studies 20
ii) Soil Variability Study 20

C. Forest Productivity and Decline Studies 21
i) Maple Decline Study 21
ii) Forest Growth Study 21
iii) Dendrochronology and Hardwood Decline Studies 22

D. Laboratory Support and Quality Assurance ... 22

TASK #4 - BIOGEOCHEMISTRY STUDIES 23

TASK #5 - SOCIO-ECONOMIC ACTIVITIES 26

A. Damages and Benefits 26
i) Financial Value Models Update 26
ii) Lake Algae Study 26
iii) The Value of Recreational Fishing 26

B. Costs of Abatement and Mitigation 26

C. Strategy Development and Evaluation Tools 27

TASK #6 - LEGAL INITIATIVES 28

A. Provincial Initiatives 28

B. International Initiatives 28

Table 1 - Interventions by the Province of Ontario 30

TASK #7 - PUBLIC RELATIONS INITIATIVES 32

Muskoka '85 Conference 32
Countdown Acid Rain 32

SUMMARY 33

APPENDIX I - INTERNATIONAL LRTAP PROJECTS 35

APPENDIX II - BIBLIOGRAPHY 40

INTRODUCTION

Substantial improvements in ambient air quality were realized in the period from 1970 to 1980; however, in the mid 1970's we became aware of damage to aquatic systems a considerable distance from any local sources of pollutants. We learned of the deterioration of lakes in south-central Ontario at about the same time as studies in the Adirondacks in New York State identified acidic deposition from both distant and nearby sources as the cause for acidification of lakes in this region. Therefore, in 1979, Ontario established the **Acidic Precipitation in Ontario Study** (APIOS) to investigate the causes and effects of the long range transport of air pollutants.

The program is organized into seven areas of work: emissions and atmospheric processes, aquatic effects, terrestrial effects, biogeochemical effects, legal initiatives, economic studies and information services. Each program area has its own specific goals. In addition, the credibility of the scientific research is assured by a documented and operational quality assurance program.

Ontario is continuing to coordinate its research and emission control efforts with other parts of Canada and the United States since the solution to the LRTAP problem requires action by all jurisdictions involved. Appendix I provides a summary of international LRTAP projects in which MOE is involved. Appendix II provides a bibliography of APIOS related publications and technical reports.

It was postulated that a loading of a maximum of 20 kilograms per hectare year of wet deposition of sulphate was sufficient to protect all but the most sensitive aquatic systems. The 20 kilogram deposition target has been adopted by the eastern Canadian provinces and the federal government. Current loadings range up to twice this level.

In working towards achieving this 20 kilogram target, the eastern Canadian provinces and the federal government agreed to reduce SO_2 emissions by 50% to 2.3 million tonnes per year by 1994 east of the Manitoba-Saskatchewan border. The 1980 base case level for the eastern half of Canada totalled 4.5 million tonnes.

Ontario went beyond the commitment it made at the federal/provincial meetings. Its Countdown Acid Rain program will reduce Ontario's emissions from the 1980 base case level of 2,194 kilotonnes to no more than 885 kilotonnes by 1994.

The new regulations are aimed at four corporate sources which together emit 80% of Ontario's SO_2. These sources are Inco, Falconbridge, Algoma (Wawa) and Ontario Hydro.

This package of emission controls was developed in consultation with each of the major pollution sources to ensure that economic activity need not be inhibited.

Control technology has not been specified and the individual companies may choose their method of abatement so long as the legal limits are met by the specified dates. The regulations provide for a three year research and development period, leading up to a final report by 31 December 1988 from each of the major sources. This report will spell out precisely how the emission limits will be met. Semi-annual interim progress reports will ensure that the Ministry keeps on top of the situation.

In addition, a new regulation has been developed to limit SO_2 emissions from new or modified oil or coal-fired boilers by placing a 1% sulphur content constraint on the fuel or requiring that an equivalent amount of SO_2 be removed from the flue gas.

A unique feature of this regulation provides an additional overlay provision based on the Ministry's mathematical model (Statistical Long Range Transport Model for Air Pollutants). New or modified boilers must not result in wet sulphate deposition greater than 0.1 kilograms per hectare per year in the southern portion of Ontario.

However, the major emission reductions in Canada will not be sufficient to achieve the 20 kilogram target. Major emission reductions are also required in the United States. All attempts to negotiate a bilateral treaty on acid rain with the United States have failed to date.

Hopefully, Ontario's realistic and practical approach in severely limiting its own emissions will encourage the United States to take similar positive action.

TASK # 1 - ATMOSPHERIC PROCESSES STUDIES

A. Emissions Inventory

The compilation of statistics on the production of SO_2, NO_x and other pollutants serves several purposes. Trends in emissions of acid-producing gases are measured and matched with changes in deposition patterns. All of the atmospheric models require as input detailed information on SO_2 and NO_x emissions, by geographic locations. Knowledge of the location and magnitude of emission sources is also essential in planning cutbacks of acid gas emissions.

During FY 1985/86, the upgrading work on the Ontario Acid Rain Emission Inventory was carried out to provide more complete information regarding SO_2 and NO_x emissions as well as related Ontario statistics. A comprehensive temporal emissions report of SO_2, NO_x and VOC from both area and point sources in Ontario, together with stack data, during August 1 to 15, 1980 was performed. The sectors in the VOC inventory were reorganized to provide a more systematic way for the processing, updating and reporting of data. The methods of compiling Ontario area emission sectors were standardized and improved to be compatible with the federal estimates. An analysis of the area emissions in Ontario for the period 1970 to 1983 was completed. A decrease in SO_2 emissions was observed while NO_x showed a slightly increasing trend. Version 2.0 of the NAPAP inventory was processed, standardized and used in the analysis of U.S. emissions.

B. Modelling and Meteorological Studies

i) Atmospheric Modelling

Mathematical models combine our knowledge of the movement of air masses and the scavenging and chemical transformation of pollutants during transport into a set of numerical equations. Output from the models can be compared to observed deposition patterns, and if the comparison shows a close agreement, we gain confidence that we have a good understanding of the causes and mechanisms involved in acid deposition. Once the models are sufficiently developed, emission reduction scenarios can be assessed by looking at resulting deposition patterns. The models can also be used for interpretation of data.

Two simple long range transport models, a statistical model and a trajectory puff model have been developed. The statistical model simulates long-range average deposition and air concentration, whereas the trajectory puff model simulates the same on a monthly and seasonal time scale. Both models were extensively evaluated, peer reviewed and used in the development of control strategies. The models have also been used in international studies such as ISDME (International Sulphur Deposition Model Evaluation).

A computer program including gas phase and aqueous phase chemistry of the atmosphere was developed, to be used in the trajectory puff models. Evaluation and application of this program is continuing. A mesoscale wind model was also developed and tested and is being used in conjunction with the trajectory puff model to study the local impacts of major point sources.

A working version of the eulerian long range transport model (ADOM) was installed at the CMC computer. The model was evaluated with OSCAR 2 and PEPE/NEROS data. Further evaluation of the model is continuing. The model results are being used to plan the joint U.S./Canadian field study to evaluate the ADOM (Canada) and RADM (U.S.) eulerian models. Once evaluated, the models will be applied to investigate the importance of non-linearity in sulphur deposition and to determine the most effective way to control emissions of SO_2, NO_x and hydrocarbons.

A project to improve the cumulus cloud parameterization in the model was started in collaboration with Electric Power Research Institute of the U.S., and Environment Canada. An inter-comparison of the various modules of the model with NCAR model will be carried out as part of this project. The project is expected to last approximately three years.

The eulerian model is computer intensive and requires a super computer (such as Cray) for efficient executions. To minimize the cost of running the model, a project was started to determine if a limited set of meteorological events could be used to simulate seasonal and annual average values. Results of this study will be evaluated in the coming months.

The primary future focus of the model development unit will be to evaluate and apply the eulerian model. The simpler statistical and lagrangian model development is essentially complete and will be used for emission control studies as the need arises.

ii) Meteorological Data Acquisition System

A meteorological data acquisition system (MDAS), capable of providing support for special studies and episode analysis, as well as modelling activities, has been implemented. MDAS is a computerized system which collects and stores meteorological data supplied by Environment Canada from the North American network of weather stations. Air parcel trajectories are also calculated by the system for interpreting event precipitation and other air quality data.

During FY 1985/86, meteorological data were acquired and archived on an on-going basis. Air parcel trajectories at various locations in Ontario and Eastern North America were calculated and archived on a daily basis. As well, the daily synoptic weather patterns for various locations in Ontario were categorized and archived.

An overview study was completed on meteorological analyses of acidic precipitation in Ontario for the period 1976 to 1983. The analyses utilize air parcel trajectory modelling and synoptic weather classification. For areas of south and central Ontario, precipitation events most commonly occur with pre-warm front and cyclonic situations, and trajectories from the south and southwest octants. Furthermore, most of the reported wet deposition of sulphur and nitrogen is associated with trajectories from these octants. High air concentrations of sulphur and nitrogen are also associated with trajectories from these octants.

C. Deposition Monitoring Networks

Deposition monitoring across the province continued, data on air and precipitation quality being collected on both a daily and 28-day basis. Audits were carried out on operations in all the regions. Development work was initiated into the daily sampling and chemical analysis of certain trace metals (As, In, Se, Sb, V), which can be used as tracers of smelting and power generation operations. Routine measurements for these metals will be commenced in FY 1986/87, and the results will aid in determining the effect of emission controls in Ontario on acidic deposition at sensitive receptors such as Muskoka.

A number of data analyses were carried out and reported on, in addition to the regular data reporting activities. Of especial note is the publication of the analysis of the Sudbury smelter shutdown period, which showed that the Inco and Falconbridge smelters contribute a relatively small percentage of the total atmospheric deposition of sulphur oxides at various receptors in Ontario. Several papers on the results from the deposition monitoring network were also presented at the Muskoka '85 Conference.

D. Oxidants Strategy Development

The results from the Sarnia Oxidants Study (June 27-July 18, 1984) were interpreted and reported. It was found that for certain weather conditions, emissions from the Sarnia area lead to measurable increases in oxidant levels in southwestern Ontario. However, the major portion of the oxidant loading is still attributable to long-range transport from the United States.

An analysis of the ozone data from the routine monitoring stations in southwestern Ontario and adjacent areas in Michigan was carried out, to assess the long-term Sarnia contribution to ozone levels.

Work was commenced, using the eulerian long-range transport model, to determine whether oxidant levels in southern Ontario can be better controlled by decreasing hydrocarbon or nitrogen oxide emissions. Results will be available in the summer of 1986.

E. Laboratory Support and Quality Assurance

A total of 64,470 tests were performed on samples collected under Task 1 this fiscal year. This represents 89% of the requested testload.

Development began late in the fiscal year of a method for sampling NH_3 in air using nitric acid impregnated W41 filters. Development of the sampling method was considered by Air Resources Branch to be their current top priority.

The Quality Assurance office of the Laboratory Services Branch continued its representation on this working group. The Deposition Monitoring Network has a well-defined and routinely implemented Quality Assurance program. The Quality Assurance Office participates by supplying control samples for the event and cumulative networks and also the 28-day accuracy study. Special concerns such as bag tests and field blanks are also addressed. The quality of data utilized in the models is an ongoing concern.

TASK #2 - AQUATIC EFFECTS STUDIES

DORSET SITE DEVELOPMENT

A new office/storage complex was erected at the Dorset Research Centre this past year. The exterior shell was completed by September 1985. Phase II construction to complete the office, computer and boardroom facilities is proceeding slowly, with a target completion date of December 1986.

The centre's computer facilities have undergone considerable upgrading. The HP-1000 computer system was fully operational by September 1985. Training programs to introduce staff to the new system were implemented December 1985 through February 1986. The capacity and potential of the new system, coupled with the increased demand as a result of changes in the emphasis of studies at the centre, prompted a feasibility study for further upgrading of the computer facilities. The recommendations of this study have been accepted and an expanded system is being purchased.

A. Chemical Studies

i) Calibrated Watersheds

a) Chemical Limnology

A set of 20 streams and 8 lakes in Muskoka-Haliburton has been monitored for periods ranging from 5 to 10 years in an attempt to measure the long-term effects of acid deposition on the chemistry and biology of these waters. The water chemistry data base for the calibrated lakes was updated and edited to December 31, 1985. Statistical summaries of stream chemistry and stream loadings are complete from June 1976 to May 1984 for all 32 calibrated watersheds. Monthly precipitation chemistry data (4-14 stations from June 1976-May 1985) and Muskoka/Haliburton area averages and chemical loads were calculated. A data report summarizing precipitation deposition is in preparation, with data current to May 1985.

Several methodology data reports concerning the calibrated watersheds were published. A summary, updating procedures used by the Limnology Unit from June 1975 to April 1986 for the field collection of lake, stream, and precipitation samples, and analytical methods used for each parameter has been completed.

Discharges from some of the calibrated watersheds are now recorded on site from the continuous stage recorders. Development of software to calculate daily discharges is targeted to be operational by mid-1986. Presently, discharge data for the 32 monitored watersheds are calculated to May 1984.

b) Lake and Stream Models

Data collected as part of the calibrated watershed studies have been used to develop and calibrate several models. A model for hydrology and streamwater chemistry has been modified for applications to one of the APIOS study lakes. The 'Birkenes-Storgama' model, developed by Dr. Hans Martin Seip (Norway), has been calibrated to simulate data for Harp #3, #4, and #6 sub-catchments for the 1980 to 1984 period. A statistical assessment indicates that the hydrology sub-model performs with good reliability over the confirmation period, and the sulphate sub-model performs fairly well. The model can be applied at new temporal and spatial locations without extensive calibration, and produces useful simulations.

Ed deGrosbois spent 10 weeks (February-April 1986) on exchange in Norway with Dr. Seip and colleagues developing and modifying models for applications to predict lake and stream chemistry and hydrology.

An estimate of the lowest number of samples required to describe annual mean water chemical concentrations was made using three of the intensively sampled APIOS study lakes. This estimate will be particularly useful in planning lake water quality surveys. This type of analysis has been done on 12 commonly measured chemical parameters.

Long-term trends in aquatic chemistry are continuing to be studied through monitoring of a selected group of 19 lakes in Muskoka/Haliburton and 16 new lakes in the Parry Sound and Muskoka/Haliburton area. Statistical summaries for the 19 and the 12 previously monitored Algonquin lakes (1981 to 1985) are complete to December 31, 1985.

c) Metal Contaminants

A new project dedicated to determining the sources of mercury (Hg) to the study lakes has been initiated. Mercury levels in streams from several calibrated watersheds of 4 lakes in the Dorset area are now monitored routinely to quantify terrestrial loadings. A new solvent extraction based technique will be used for the analysis. Very low detection limits have been achieved with this method, and it is expected that the major sources of Hg to the lakes will be identified in the next two years.

ii) Extensive Lake Sampling

This program is carried out in cooperation with the Ministry of Natural Resources, and is designed to delineate the magnitude of Ontario's aquatic resource at risk due to acidification. The results of sampling 5,341 lakes in the province were published. It was found that 4% were acidified (alkalinity ≤ 0 ueq$\cdot l^{-1}$) and further 14.8% were extremely sensitive (alkalinity >0 ueq$\cdot l^{-1}$ and <40 ueq$\cdot l^{-1}$).

The majority of the acidified lakes are in an elliptical area around Sudbury, stretching to the northeast and southwest of the city. However, an increasing number of acidified lakes are being identified in other areas of the province, including Algonquin Park, Muskoka-Haliburton, Algoma, and Parry Sound. Mostly, these acidified lakes are small headwater lakes, but their distance from point sources implicates long range transport of acids as the cause of acidification.

Many of the lakes close to the Sudbury smelters show signs of significant improvement related to declines in sulphur dioxide emissions. This is seen as a very encouraging result, since it demonstrates that abatement of sulphur dioxide will result in tangible improvements in the water quality. The degree of improvement in the lakes in the Sudbury area was correlated with their proximity to the smelter. A subset of about 50 Sudbury area lakes is being sampled annually to monitor any ongoing trends.

Another result of the extensive lake survey has been the identification of three acidified lakes in Pukaskwa National Park, in northwestern Ontario. These are the first acidified lakes found in this region, and they are unique in Ontario since they appear to be going acidic under a fairly low rate of wet sulphate deposition. The first year's sampling of deposition indicates that the total sulphate deposition in the area is about 16 kg/ha·yr. An analysis of the water chemistry results indicates that sulphuric acids, and not natural organic acids, are responsible for the water acidity in these lakes.

MNR is currently performing a few selected lake surveys and combining these data with Department of Fisheries and Oceans data to determine how accurately their currently biased sample (biased towards large lakes and sportfish lakes) predicts regional water chemistry.

B. Biological Studies

i) Algae

a) Filamentous Algae

Lake acidification produces noticeable alterations in plantonic and benthic algal populations. In particular, some forms of filamentous algae are favoured by acidic conditions. Filamentous algae can colonize extensive areas of the littoral zone of acidified lakes and may reduce fish spawning areas, as well as constitute an aesthetic nuisance.

The increase in filamentous algae growth has been observed in experimentally acidified lakes in the Experimental Lakes Area of northwestern Ontario. Work done in FY 1984/85 suggests that filamentous algae populations can be reduced significantly by lake neutralization. Algal surveys had been performed on Bowland Lake prior to its neutralization in 1983. Detailed, whole-lake mapping of Bowland Lake in 1984 indicated that the algal coverage had been greatly reduced. Whole lake mapping is continuing to follow changes in filamentous algal populations.

b) Odour Production by Chrysochromulina breviturrita

No new cases of odour produced by C. breviturrita were reported from Ontario for the April-September period of 1985, although Cinder Lake (Hindon Twp.) experienced a recurrence of the problem in late June and July. The species was reported from several lakes in North and South Carolina during 1985 and the known distribution now includes four states and Ontario. Recent work has centred on light and temperature requirements, nitrogen nutrition and the development of analytical methods for low levels of selenium in lakewater (Se has been shown to be a requirement for growth).

c) pH Change and Algal "Fossils" in Lake Sediments

The study of algae and diatom communities in acid lakes has some interesting applications. Diatoms and some types of algae (chrysophytes) leave remains in the sediment which do not decompose. By carefully characterizing the diatom or chrysophyte communities in a number of lakes over a range of pH's, a "calibration" can be developed which relates the pH to community composition. This calibration can then be applied to the chrysophyte or diatom remains in a sediment core and the pH history of the lake can be reconstructed.

A draft statistical analysis of some of the data from the calibration lake set (55 lakes) has been completed for the diatom data. The chrysophyte data are still being generated. In order to save time, the chrysophyte identifications are proceeding along with the taxonomy development. Several species have been found which have not been reported previously from North America. Six papers on Mallomonas taxonomy were prepared for journal submission (1st drafts). Sediment cores from two acidic Pukaskwa National Park lakes and from two low colour lakes near Parry Sound (pH 4.9) were collected in August. Preparation of these core sections (acid digestion, slide mounting, etc.) was completed and analyses begun.

ii) Zooplankton

A computerized method for the identification, measurement and tabulation of zooplankton species is now fully operational. The Zooplankton Counting System (ZEBRA) tabulates different species and estimates biomass based on known length-weight relationships. Samples collected from APIOS study lakes have been analyzed and reported to December 1985.

Three papers concerning zooplankton species in Muskoka/ Haliburton and the Sudbury area are currently under review.

iii) Invertebrates

Studies on stream invertebrates in Algonquin Park continued during the 1985 field season, and will resume again in the 1986 field season. These studies are designed to determine if changes in stream insect communities have occurred due to increased acidification in Algonquin Park, Ontario. Further analyses indicate that these acid-stressed aquatic ecosystems have species assemblages that are tolerant to anthropogenically induced acid deposition. These studies are utilizing the continuous data base established during the 1930's by Dr. F. Ide from the University of Toronto.

iv) Fish

a) Laboratory Studies

Acute Toxicity

The sensitivity of native fish to pH depressions in streams and lakes has been assessed over a 5-year period (1981-1986). Work is complete for the determination of the lethal pH thresholds for the most sensitive stages of lake trout and brook trout. It appears that the early life stages are the most sensitive and that toxic conditions occur at or near the inflows of some streams during snowmelt. Hydrogen ion is the most likely toxic factor, but aluminum may also affect survival.

Experiments to determine the lethal pH and aluminum thresholds for other native Ontario fish species, and factors that modify hydrogen and aluminum ion toxicity were studied in April 1985. The results of these studies were presented at the Muskoka '85 Conference. It appears that survival of salmonid early life stages in acidified waters is controlled mainly by hydrogen ion with aluminum toxicity restricted to cases where its concentration exceeds saturation or H-ion exerts an a-priori effect.

Chronic Toxicity

Complementary experiments were conducted by MNR to determine whether pulse exposure of lake trout embryos to acidic melt water produces sublethal effects on growth, whole body ions, feeding and predator avoidance. Short exposure of lake trout embryos to realistic pH and Al conditions reduced yolk conversion efficiency, resulting in smaller swim-up fry. Pre-exposed fish were less efficient at catching prey (Daphnia magna) and preliminary findings suggest that pre-exposed fry are also less able to avoid predators. The sublethal effects on size, feeding and predation may combine to reduce survival in the wild prior to deterioration of whole lake chemistry to acutely lethal conditions.

b) Field Studies

Comparative Lakes Project

MNR is testing laboratory derived pH and Al toxicity thresholds in the field through the evaluation of data on relative abundance, age, structure, growth, recruitment success, diet and levels of certain contaminants. Species examined include lake trout, brook trout, smallmouth bass and walleye. Studies were conducted to verify that spring pulses of low pH water containing high concentrations of aluminum occur on natural lake trout spawning shoals in the Muskoka-Haliburton area, and to determine if there are resultant detrimental effects on lake trout survival. In-situ bioassays of lake trout eggs and fry at 10 Dorset area lake trout spawning shoals, indicate that higher total mortalities (egg and fry) were associated with the lakes of low pH, and higher aluminum concentrations.

Studies of Fish Kills on Plastic Lake

A new project investigating spring-time fish kills in an acidified lake (Plastic Lake) was initiated by MOE in the spring of 1986. Increased hydrogen ion and aluminum loadings to the lake during spring snowmelt and rainstorms have been suggested as the causative agents. This study is designed to determine the cause(s) and extent of the annual fish kill by integrating lab testing with in-situ exposures, and to investigate factors such as over-population, parasitism and nutrition which may predispose the population to H-ion/Al stress. The existence of the phenomenon in other lakes will be examined.

Trend Through Time Studies

MNR is establishing a quantitative baseline description of community composition and population characteristics of major fish species in order to assess community changes in response to acidification and other stresses. Survey data from approximately 2,900 Ontario lakes were used to examine the distribution of 12 fish species with respect to lake pH. Yellow perch, white sucker, brook trout, pumkinseed, fathead minnow and redbelly dace were found to be well distributed in low pH lakes (pH <6.4). These species were classified as being tolerant of low pH. Lake trout, common shiner, blacknose shiner, lake whitefish, walleye and northern pike showed limited distribution in low pH lakes (pH <6.4). Lake whitefish and northern pike were found to inhabit large northern lakes which are generally less susceptible to acidification stress when compared to small southern lakes. The limited distribution of these species likely relates to zoogeographic factors rather than their intolerance to low pH. However, without historical data, one cannot determine if decreased distribution of the various species in low pH systems is due to intolerance to low pH.

Studies continued to determine the number, biomass, mortality rates and recruitment of exploited lake trout populations in acidifying lakes. Continuous creel census, tag returns and a reassessment of population status in the fall of 1986, will provide an understanding of the response of lake trout populations, in acidifying lakes, to differing levels of exploitation.

MNR examined the response of selected fish species to acidification by assessing the population status (abundance, age, structure, growth, etc.) in a set of lakes which span a gradient in pH. In-situ bioassay techniques and introductions were used to confirm population status (e.g. recruitment failure) and supplement current understanding of species response to low pH. A model (Beggs et al., 1985) that uses lake water quality (especially pH) to predict the status (viable or failing to recruit) of lake trout populations was tested by surveying populations in 14 known lake trout lakes of unknown current population status. Predictions about status were confirmed in 13 of 14 lakes. In the single exception, the pH determined at the time of the assessment was significantly higher than that used to make the prediction.

Preliminary analysis of brook trout populations in lakes of pH 4.5 to 6.3, suggest the threshold pH for brook trout populations is approximately 5.0. Unlike the situation in lake trout lakes, no evidence of recruitment failure was observed in brook trout lakes of pH slightly higher than the threshold pH. Five additional brook trout lakes were assessed in 1985.

Mercury Uptake

Hg levels in adult sportfish from some 1,300 locations in Ontario have been analyzed by MOE since 1977. These data will be used to investigate broad scale relationships between Hg residues and acidic deposition, Hg residues and water quality parameters and relationships in adult sport fish versus juvenile perch.

Studies were conducted by MNR to examine the relationship between body burdens of mercury (Hg) in lake trout and lake physical-chemical characteristics, focusing on those chemical parameters known to be related to acidic deposition. Researchers have shown that at low pH, biological methylation of mercury results in the formation of highly toxic monomethyl mercury which is accumulated in fish. At higher pH's, dimethyl mercury is formed which is less toxic and is not accumulated in aquatic biota. Using stepwise multiple regression analyses, dissolved organic carbon was consistently selected as the single best predictor of mercury concentrations in lake trout of a standard length (44 cm), explaining as much as 45% of the between lake variation in mercury concentrations. Between lake differences in the rate of mercury uptake by lake trout were also examined using analyses of covariance. Hg uptake rates in lake trout were similar in the majority of lakes examined. Uptake rates were significantly different in lake trout from several lakes located in Algonquin Region. Uptake rate was found to be related to lake pH and lake elevation (highest uptake of Hg in high elevation and low pH lakes). For lake trout with similar uptake rates, Hg concentration at any particular length was found to be related to lake concentrations of dissolved organic carbon and total aluminum (high Hg at length in high dissolved organic carbon and high aluminum lakes).

v) Wildlife Studies

The Ministry of Natural Resources has conducted field studies to determine the relationship between acidic conditions and amphibian distribution and abundance in 40 ephemeral ponds and pools in the northeastern region adjacent to Sudbury. In some ponds with depressed pH, levels of inorganic monomeric aluminum were elevated above those which were reported to inhibit hatching success of the wood frog. In 20% of all ponds surveyed levels of total aluminum, aluminum fluoride and inorganic monomeric aluminum exceeded by several times those reported to reduce hatching success in the American toad.

A three year study was carried out near Killarney in the northeastern region to investigate the relationship between water quality variables associated with acidification and the reproduction of the Eastern Kingbird. Metal enrichment of the diet (emergent aquatic insects) of these birds was also examined.

The major percentage of variation in kingbird reproductive factors measured (including egg weight loss and bone growth) was explained by genetic differences between siblings or by environmental differences between nests. However, an additional amount of variation was explained by water chemistry which was influenced by lake acidification. Metal enrichment of aquatic prey insects was related to acidity in the study lakes. Elevated levels of mercury in Killarney kingbird nestlings were seen in comparison with buffered regions removed from the Sudbury influence.

Data are also available to address the role of natural or organic acidity in the Killarney area wetlands where the wildlife-related studies were carried out. These data indicate that acidity comes predominantly from sulphates and that organic acidity plays a minor role in the Killarney study sites.

The moose is a game species which feeds extensively in aquatic habitat during summer months. Swedish studies in 1981 reported high concentrations of cadmium in moose liver and kidney which, in some instances, exceeded World Health Organization standards. Preliminary work carried out by MNR in one area north of Huntsville showed a broad range of cadmium concentrations in moose kidney, ranging from trace levels to those which are higher than those acceptable to the World Health Organization. However there was no attempt in this preliminary work to correlate cadmium accumulation with patterns of atmospheric deposition.

D. Remedial Methodologies Development

Recognizing that lake neutralization is at best a temporary measure to delay or reverse the effects of acidification, Ontario is pursuing the development of lake neutralization expertise as a method of protecting and rehabilitating lakes. Even under the most optimistic of emission abatement scenarios, the significant reduction of acid inputs into many of Ontario's lakes is several years away. Lake liming may prove to be a feasible interim measure for the protection of important gene pools, or the rehabilitation of significant sport fisheries.

In August of 1983, the first of two whole-lake neutralizations occurred. Bowland Lake was neutralized with 85 tonnes of finely powdered calcite. The limestone was applied in August by a Canso water bomber, and the pH of the lake was raised from about 5.1 to approximately 6.8. Prior to neutralization, Bowland Lake water was toxic to lake trout. Yellow perch still existed in the lake in a numerous but stunted population. The indigenous lake trout and white sucker populations had disappeared in the late 1960's, and repeated efforts to stock the lake had failed.

After neutralization, fingerling, yearling and adult lake trout were introduced to the lake. So far, the trout seem to be surviving, and some attempted spawning was observed. The survival and reproductive success of the stocked trout will continue to be monitored.

The second whole-lake neutralization occurred in May, 1984. Trout Lake, near Parry Sound, was a low alkalinity lake, with a self-sustaining trout population. The liming of Trout Lake demonstrated no adverse biological effects associated with lake liming. No significant mortality occurred in lake trout or in rainbow trout suspended in cages around the lake during the liming operation.

Improvements in liming technique were also made. The Bowland Lake liming used dry calcite powder, and a dissolution efficiency of a little over 50% was achieved. Slurrying the calcite with a dispersant and water resulted in a dissolution efficiency greater than 90% in Trout Lake.

Preliminary experiments investigated the feasibility of treating lake trout spawning shoals with crushed limestone. In acidic Laundrie Lake, near Sudbury, incubation of lake trout eggs/sac-fry within plots of natural and limestone rubble showed improved survival in the limestone plots. Supporting behavioural studies in non acidic Miskokway Lake, near Parry Sound, indicated that spawning lake trout do not avoid natural shoals artificially covered with limestone. An expanded experiment with more plots is currently underway on Laundrie Lake, and additional site specific liming studies are planned for the future.

The lake neutralization study is a joint MOE/MNR program being conducted under contract.

E. Laboratory Support and Quality Assurance

The total Water Quality Section testload for Task 2 during fiscal year 1985/1986 was 172,492 tests, a 13% reduction over last year's total but it represents 99.9% of the budgeted testload.

The Inorganic Trace Contaminants Section performed a total of 23,906 tests for Task 2 in fiscal year 1985/1986. This represents an increase of over 18% over fiscal year 1984/1985 and a 9% increase over the number requested for 1985/86.

The total number of tests analyzed at the Dorset laboratory for FY 85/86 was 87,240. The Laboratory Services Branch group on site is now using an HP-3000 computer system to input all sample and chemical analysis data to the Laboratory Information Services System (LIS). This process was fully operational by November 1, 1985.

Two new mobile laboratories are now on-site at Dorset for mercury-source studies and for the soils laboratory (LSB) for the biogeochemistry project (Task 4).

During August and October of 1985 an intensive inter-comparison of ion chromatography versus the historic MTB colourimetric method for SO_4 measurement was carried out to establish a relationship between the two methods so that historic MTB SO_4 data could be salvaged. Nearly 2,500 analyses were carried out resulting in the study meeting its objective.

Staff established an automated colourimetric method for aluminum analysis based on catechol violet buffered with hexamine. It uses hydroxylamine hydrochloride plus phenanthroline to eliminate iron interference. The method has been on-line since December 1985 and has replaced dialysis/ MIBK extraction/FAAS analysis as the method for aluminum speciation.

The Quality Assurance programs of the Aquatic, Biogeochemical and Terrestrial Tasks made considerable progress in the past fiscal year. The Quality Assurance Plan was drafted by two Canada Works contractors outlining the components of individual projects which must be documented for Quality Assurance purposes. They then began gathering information from project leaders of the three tasks to identify what documentation needed to be supplemented. In February 1986, this work was contracted out with the objectives of compiling Quality Control and Procedures Manuals for each project. A report giving the results of an audit of Tasks 2, 3 and 4 Quality Assurance programs is expected in September 1986. Thereafter, the Quality Assurance Office will continue its input into APIOS in a monitoring, advisory and auditing role.

TASK #3 - TERRESTRIAL EFFECTS STUDIES

A. Vegetation Studies

i) Lichen and Bryophyte Study

Lichens obtain a substantial portion of their nutrients from the air and from precipitation. Since their chemistry reflects concentrations and deposition of atmospheric elements, they have been used as air quality indicators.

Lichens and mosses have been obtained and chemically characterized from approximately 50 locations across Ontario. Variability in chemical composition at given sites and during the growing season have also been determined. Interspecific comparison of chemical content between two lichen species has revealed close similarities, while significant differences have been observed between lichens and mosses.

Metal levels in lichens are strongly influenced by their proximity to major sources of metal-contaminated particulates. The sulphur content of lichens exhibits a south-to-north decrease in concentration. The elemental composition of wet deposition can account for only part of the variability seen in the chemical content of lichens. Gaseous and airborne particulate materials and perhaps the chemistry of the substrate, may also be required to account for the remaining variability.

Other activities under the Lichen and Bryophyte Study included inventories of species at three biological sites (see Task 3C) and the establishment of photometric plots of lichens to determine growth rate.

This study was concluded during FY 1985/86 with the analysis of the data being the primary activity. An interpretative Final Report was in preparation and will be available in the near future. Voucher specimens of lichens and mosses from across the province will be deposited in the herbaria of regional and ARB offices.

ii) Vegetation Studies - Mobile Rain Exclusion Canopies

These studies are designed to assess the impact of acid deposition and associated air pollutants on commercially important crop species.

FY 1985/86 saw the second year of experiments conducted in the Mobile Rain Exclusion Canopies at the MOE Phytotoxicology laboratory in Brampton. These are greenhouse type canopies (3), installed on tracks, which can be moved over crops during rain events and retracted when the rain events are finished. Under the canopies, a grid of nozzles applies synthetic rain of differing chemistries to crop plants. The synthetic rain is

applied in the same amount and at the same time as the rain event outside. At the end of a rain event, the canopies retract, leaving the crops exposed to ambient conditions.

All phases of the exclusion canopy operation are automated, from detection of a rain event, deployment of the canopies, mixing and application of the treatments and retraction of the canopies. Another feature of the system is a set of blowers and pillows which can be deployed between rows of crops. If ambient air monitors detect elevated levels of SO_2, O_3 or NO_x, the pillows are inflated and produce streams of pollutant filtered air around the crops, thereby reducing the ambient air concentration of the pollutants in the vicinity of the plants. In the future, the pillow system could be used to "spike" the surrounding air with increased concentrations of pollutants, so that the interaction between acid deposition and air pollutants could be studied.

The results of the 1985 field study (to determine the effects of simulated acid rain treatments on soybean) indicate that increased acid content of simulated acid rain had a significant "stimulatory" effect on soybean yield (kg/ha). Yield was determined from total soybean seed weight harvested from 1 m^2 area of each treatment plot. However, detailed measurements performed on subsamples of these harvests (10 plants per plot) showed no significant treatment effects on plant height, pod number per plant, seed number per pod, and seed number per plant. The study will be repeated with soybean (cv. Hodgson) for a third and final time in 1986.

A cooperative study has been arranged with the Institut fur Producktions und Okotoxicologie, Braunschweig, West Germany whereby a member of their staff is planning to visit the Phyto lab during August 1986 to collect soybean plant samples for biochemical analysis. The air exclusion system will be operational for the duration of the field season for this study. Treatment plots will be exposed to controlled fumigations of ozone in order to determine joint effects of simulated acid rain and ozone on soybean yield.

iii) Vegetation Studies - Greenhouse Experiments

During 1985, experiments with greenhouse grown plants were also conducted using indoor rain simulation chambers. Seedling sensitivity of corn cultivars was determined as monitored by germination and dry shoot and root biomass during the spring of 1985. This was the final set of experiments for a two year indoor study to rank sensitivities of 24 crop cultivars, (i.e. alfalfa, barley, cabbage, cucumber, corn, soybean). For each crop, plants were exposed to 8 simulated acidic rain treatments - pH 2.6 to 5.6. The results indicated that plant response to simulated acidic rain is not only species dependent but also strongly cultivar dependent.

An indoor experiment was conducted to investigate the joint effects of simulated acidic rain and gaseous air pollutants on the growth and yield of potted Hodgson soybean plants. Plants were subjected to 6 simulated acid rain treatments and 3 ozone exposure levels on alternate days in rain chambers and fumigation chambers respectively. Results suggested that plant biomass is reduced by ozone but not by simulated acid rain. The experiment will be repeated in 1986.

The initial phase of an indoor experiment with potted radish plants was conducted to determine the effects of simulated acid rain application (frequency, duration and acidity) on dry shoot and dry root biomass. Preliminary results indicate that foliar injury and reduction in biomass are both affected by all three variables. Additional experiments will be conducted in 1986.

B. Soil Studies

i) Baseline Studies

This study was designed to document changes in soil due to acidic deposition. Since 1980, over 400 soil baseline sites have been sampled across Ontario. In FY 1985/86, five soil sites, originally sampled in 1980, were resampled in order to monitor changes in soil properties which may have been caused by acidic precipitation. Editing and compiling of baseline soil data collected in 1982-83 were undertaken in FY 1985/86. A second report on the Soil Baseline Survey will be prepared to complete this soil database.

ii) Soil Variability Study

Natural variations in soil can limit the ability to detect changes in soil caused by acidic deposition. At the two southern Ontario biogeochemical study sites, soil was sampled repeatedly to determine the spatial and seasonal variability of soil properties.

A poster (prepared for Muskoka 1985) presented the variability of five soil sensitivity parameters over two years of sampling. Spatial variability can be reduced by taking replicate samples. Seasonal variability, however, is less predictable. The results from this study indicated that most parameters tend to be less variable in the summer. In addition, it may be more appropriate to use base saturation when assessing soil sensitivity as opposed to pH due to its lower coefficient of variability.

C. Forest Productivity and Decline Studies

i) Maple Decline Study

This study was initiated in 1984 to determine the role that acidic deposition is playing in the decline of woodlots being managed for maple syrup production in the Muskoka/Haliburton area of Ontario. Permanent observation plots were established to assess tree condition and each of the 8 woodlots were intensively sampled. A report on the results of the 1984 sampling program was published in FY 1985/86 indicating that acidic deposition was an additional stress to the severe epidemic of forest tent caterpillar in the late 1970s, combined with spring droughts in 1976, 1977 and 1983. Armillaria mellea, tree age and site management also were contributing factors.

In 1985/86, all plots established in 1984 were re-assessed for changes in tree condition. An additional three sites were sampled; one in Algonquin Park in an unmanaged stand, and two near Peterborough on calcareous, well-buffered soil. The results of the 1985 field investigations will be compiled in a final report in FY 1986/87.

A joint OMAF/MOE questionnaire was distributed to 600 Ontario Maple Syrup Producers Association members to ascertain their perception of the decline problem in their own woodlots. Fifty percent of the members responded. Of those, 1/3 felt that there was a decline problem in their woodlots. Decline was most common amongst producers in Prescott and Elgin Counties and in the Parry Sound District. However, there were no consistent geographical trends in decline severity across the province.

ii) Forest Growth Study

Concern has been raised by studies in the United States and Europe that acid deposition and other air pollutants may play a role in the reduction of tree growth rates.

This tree growth study is being conducted by the University of Toronto's Faculty of Forestry with APIOS funding. It is a continuation of a study which began in 1962.

Originally, trees were tagged and measured on a number of lots in the vicinity of Dorset. The trees were remeasured in 1972 and again in 1983 and 1984. This unique record provides an opportunity for a detailed analysis of tree growth and stand dynamics and attempts to examine the effects of acidic deposition on these features. Factors including climate, disease, disturbances, site condition, tree age and competition all must be evaluated and quantified before air pollution stresses can be interpreted. An effort to index individual tree competition stresses was a major field activity during the

summer of 1985. Trees in the study plots were assessed for competition by neighbours using angle of influence measurements.

iii) Dendrochronology and Hardwood Decline Studies

The dendrochronology study of sugar maples is designed to determine whether growth decline is occurring across the province within 3 forest sectors. Fifty-four plots have been sampled both destructively and by extracting increment cores. Data analysis using the Tree Ring Increment Measurement (TRIM) System are currently underway. Ultimately, growth chronologies for sugar maple trees in Ontario will be produced which will provide valuable baseline information when comparing future changes in forest growth.

In FY 1985/86, a contract was awarded to determine the incidence and severity of hardwood decline across the province and to establish growth chronologies for sugar maple in the province. A survey of sugar maple stands is in the process of being conducted by establishing a series of permanent observation plots across the province. Each tree within the plot is rated according to the amount of dead branches, chlorosis and undersized leaves in the crown. By 1986, over 100 plots will have been established and assessed. Data from this survey are not expected until FY 1986/87.

D. Laboratory Support and Quality Assurance

Water Quality Section performed 43,589 analyses associated with Task 3, 68% of the approved workload for fiscal year 1985/1986 and a 21.7% reduction of the testload from fiscal year 1984/1985.

Inorganic Trace Contaminants Section performed a total of 52,521 tests for the Task 3 programs in fiscal year 1985/1986, 54% of the tests budgeted and a reduction of 7.5% over fiscal year 1984/1985.

During the fall of 1985, the soils lab was transferred to Dorset to handle the APIOS soils work and a low-level special fluoride workstation was set up. A new lab trailer and analytical equipment were purchased. The lab was installed and all equipment was received by the end of this fiscal year.

With the special analytical requirements for low-level metal analysis in Dorset, a clean room (Class 100) was required. Construction of the facility began late in the fiscal year and new analytical instrumentation was purchased (two ASV units, one with an autosampler). The clean room is expected to be in full operation by July 1986.

A new methodology (automated colourimetric) for performing aluminum analysis was developed. Aluminum speciation work is now being carried out in Dorset.

TASK #4 - BIOGEOCHEMISTRY STUDIES

Biogeochemistry studies are designed to provide detailed information on the physical, chemical and biological state of a study watershed and to document changes in this state with time. Such information is a prerequisite for quantifying the magnitude of chemical fluxes between ecosystem components and evaluating the role of acid deposition in altering these fluxes. The study results will show how interactions occur between precipitation, vegetation and soil and how the chemistry of water discharged to aquatic systems is affected.

Since results from these studies will be key to the success of the overall APIOS program, it was decided in the summer of 1985 that a separate task should be established to deal exclusively with the biogeochemistry studies. This task now integrates components of Task 2A "Calibrated Watershed Studies" with the previous Task 3C "Biogeochemistry Studies".

The biogeochemistry program in FY 1985/86 consisted of four sites located in three deposition areas: high, moderate and low.

Routine monitoring at all four sites included deposition, throughfall, stemflow, soil water, ground water and litterfall. In addition, forest stand inventories and forest soil surveys have been completed; biomass studies are underway; soil profiles have been sampled and litter decomposition studies have been conducted.

In the Muskoka/Haliburton area, where annual wet sulphate deposition is approximately 30 to 35 kg/ha·yr, two contrasting terrestrial watersheds have been under intensive study since 1981.

During 1985/86, in addition to the routine monitoring, the sampling of organic soils within the study watersheds was completed. A tentative soil map for each study catchment is on file. Maps showing the elemental concentrations at a given sampling site were prepared for both subcatchments. A stand table was prepared for each study basin. Additional field work was carried out to measure the height-diameter relationship of trees classified as major and minor species. Biomass and nutrient biomass equations for white pine and maple species were developed, preparatory to the estimation of biomass and nutrient biomass in the study watersheds.

At the Hawkeye Lake site in northwestern Ontario, the annual wet sulphate deposition is about 10 kg/ha·yr. An analysis of incident precipitation showed an average pH value of 4.78. Therefore, the Hawkeye site provides a control for comparison with the heavily loaded southern sites. In addition to the ongoing routine monitoring, the following studies were undertaken during FY 1985/86. Topographic maps of the

watershed have been completed. A report describing the results from the forest inventory and forest biomass/bioelements studies was completed, and a draft report on the standing crop biomass study is under preparation.

The second northern site is located at High Falls in northeastern Ontario where annual wet sulphate deposition is about 20 kg/ha·yr. It represents a site intermediate in deposition between the two southern sites and the northwestern one. Several studies were completed in addition to the routine monitoring work in FY 1985/86. Maps showing the base content of soils in northeastern Ontario were prepared. A study was undertaken to determine the role of forest shrub and herb canopies on precipitation chemistry. The results reported increased loadings of most major ions beneath all canopies showing that calcium, magnesium, potassium, sulphate and phosphate are all being leached from the canopy. By contrast, both nitrate and ammonia were retained. The pH values of most throughfall increased throughout the growing season and decreased after leaf fall, indicating that changes in quantity as well as physiological maturity of foliage over the growing season influenced the quality of precipitation reaching the soil.

During FY 1985/86, the current design of the biogeochemistry program was reviewed and integration with the aquatic program was initiated.

The field studies for the Hawkeye Lake, Plastic Lake and Harp Lake sites were redesigned for FY 1986/87. Monitoring at High Falls will be discontinued. Data interpretation, however, will be emphasized during the next fiscal year before a final decision is taken with respect to the continuing field operation of any of the sites.

A trace metal sampling program was originally initiated under Task 2 and then transferred to Task 4. Its purpose is to determine the major sources and sinks of cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn) in the calibrated watersheds currently being studied. Precipitation inputs, soil water seeps, lake inputs and outflows are presently monitored, with expansion to profiles through anaerobic lake hypolimnia and soil horizons this year.

Because of the low concentrations expected, considerable emphasis has been place on analytical methodology. Three clean room/hood facilities are on site with GFAAS and DPASV analytical methodology of almost sufficient sensitivity to monitor ambient levels. A few improvements are being implemented to increase sensitivity to the ng/L range.

It appears that the soils are major sinks for Cd and Pb. Conversely, acidification releases Zn from the soils.

Aluminum geochemistry in catchments stressed by acid deposition is still being investigated. Special emphasis is placed on comparing the new analytical techniques for speciating aluminum by an automated ion-exchange method with the older dialysis method. Mineralogical differences between Plastic Lake and Harp Lake soils will also be investigated in laboratory leaching experiments.

Several specific projects were deemed of great importance and study designs have been developed to address the effect of acid deposition on the natural mineral weathering rates of bedrock and till on the Precambrian Shield and on the aluminum and sulphur cycles.

Since projects of this type are still fairly new, the program design will require constant review and revision. However, the current cooperation and interest, both internal and external to the Ministry, will ultimately ensure valuable results for the APIOS program and other areas as well.

TASK #5 - SOCIO-ECONOMIC ACTIVITIES

A. Damages and Benefits

i) Financial Value Models

At the request of the Associate Deputy Minister, a study was initiated to review and, if necessary, to revise the forestry, agriculture and materials sub models of the Ministry's Financial Value Model system and to update the relevant data bases. This work was contracted out and a report is expected by the fall of 1986.

ii) Lake Algae Study

Recent evidence suggests increasing acidification has resulted in the increased growth of filamentous algae which can form slimy, unpleasant aggregates in near shore areas and Chrysochromulina breviturrita which produces a garbage dump odour. A study to obtain an accurate assessment of the incidence of these algae and their impact on lake use has been initiated. The cost of field surveys would be prohibitive; therefore, lakefront cottage owners are being surveyed to determine their perceptions of algae and other lake conditions. The use of residents' perceptions to sample the extent of these organisms and their effects, represents an innovative approach to gathering information on environmental conditions which may have applicability elsewhere.

The first phase of the study involved a full scale pilot test on ten lakes during the summer of 1985 to establish the validity of the proposed methodology. The results indicate that lake algae conditions can be accurately classified using cottagers' perceptions. A full-scale survey is now underway that includes 6,000 cottagers on 200 softwater lakes in central Ontario. Completion is scheduled for early fall 1986.

iii) The Value of Recreational Fishing

The DPA Consulting Group Inc. was also retained to conduct a study of the beneficial attributes of recreational fishing in lakes which are the object of rehabilitation and protection efforts. This study will focus on those benefits accruing to recreational anglers and will apply a contingent valuation methodology. The results of this study will be applicable to measuring changes in fishing quality and activity, whatever the cause.

B. Costs of Abatement and Mitigation

No specific studies of abatement costs have been carried out by the Ministry. Firms which are subject to control programs have submitted cost estimates of their own which have been reviewed and considered in the development of the Countdown Acid Rain program which was announced in December 1985. For more details of this program see Task #6.

One of the provisions of Countdown Acid Rain is the periodic reporting of abatement costs that are anticipated or will be incurred.

C. Strategy Development and Evaluation Tools

A final report was submitted by M. Fortin and Associates which compared Screening Model results obtained by long range transport coefficients from the MOE Statistical and the Lagrangian Models.

These results and others from the Screening Model were used in the development of the Countdown Acid Rain program.

TASK #6 - LEGAL INITIATIVES

A. Provincial Initiatives

Since 1980, Ontario has believed that there was sufficient evidence to implement SO_2 controls immediately while research continues to evaluate the benefits of these controls. As a result, Ontario was the first jurisdiction in North America to mandate emission controls based solely on the effects of long range transport of air pollutants, as distinct from local ambient air quality standards.

In July, 1980, Inco was required to cut SO_2 emissions from its Copper Cliff smelter from 2,366 to 1,769 tonnes per day by December 31, 1982. The former limit had been set based on ambient air quality, while the latter considered long range transport as well. In February, 1981, Ontario Regulation 73/81 was enacted limiting Ontario Hydro's annual SO_2 emissions to 390,000 tonnes by 1986 and 260,000 tonnes by 1990.

In the absence of an acid rain agreement with the United States, the eastern Canadian provinces and the federal government decided in March 1984, to take unilateral action and reduce their sulphur dioxide emissions to a ceiling of 2.3 million tonnes by 1994, a 50% reduction from the 1980 base case year. On February 5, 1985, they further agreed to a series of steps to achieve the first 1.9 million tonnes of this reduction and committed to determining the allocation of any further reductions in sufficient time to achieve the 1994 objective.

In December, 1985, Ontario announced its Countdown Acid Rain program and put into place the regulations which require substantial further reductions of the emissions which contribute to acid rain. Almost 80% of all Ontario-produced SO_2 emissions come from four sources; Inco, Ontario Hydro, Algoma Steel (Wawa) and Falconbridge. The regulations require a series of staged reductions to allow time to acquire and install new pollution abatement measures or new, less polluting technology to meet the new limits by 1994. The new limits require reductions from a permitted Ontario 1980 base case of 2,194 kilotonnes to less than 885 kilotonnes. For further information on Ontario's Acid Gas Control Program 1986-1994, please refer to the report entitled Countdown Acid Rain.

Countdown Acid Rain will do more than just help Ontario's environment start back to normalcy; it will also reduce acid rain in Quebec and the northeastern United States.

B. International Initiatives

Although Canada and the United States agreed to enforce existing laws and regulations in a way which is responsive to the problems of transboundary air pollution, the United States Environmental Protection Agency has proposed revisions in State Implementation Plans (S.I.P.'s) under Section 110 of the U.S. Clean Air Act which would lead to increase in allowable sulphur dioxide emissions from coal-fired power plants. Therefore, Ontario has undertaken to participate in those U.S. proceedings

which could affect, as a result of long range transport, the province's environmental quality. Ontario's efforts have been directed at encouraging the U.S. EPA Administrator and state governments to disapprove any S.I.P. revisions which would result in any increase in permissible emissions of SO_2 in the U.S. A summary of Canada's activities in this area since 1981 is provided in Table 1.

Throughout FY 1985/1986, Ontario monitored developments in the suit filed by the States of New York and Pennsylvania and several environmental groups under Section 126 (Interstate Pollution) and Section 115 (International Pollution) of the U.S. Clean Air Act. The EPA Administrator was requested to issue a final decision on the Section 126 petitions filed in June of 1981 and to give notice to the Governors of States whose air pollution endanger the health and welfare of Canada to revise their S.I.P.s to prevent or eliminate harm. On December 10, 1984, the EPA denied the Section 126 petitions on the grounds that the States did not adequately support their claims of injury. The decision on section 126 was appealed to the U.S. Circuit Court of Appeals and argued in December of 1985. The section 115 decision was appealed as well and argued in May 1986. Both judgements have been reserved.

On October 24, 1985, Ontario requested intervenor status in a similar appeal by power companies, the EPA and the States of Ohio and Kentucky against the Section 115 ruling made by former Administrator Costle. This status was granted. Ontario's oral argument was heard by the court on May 15, 1986 and judgement has been reserved.

Table 1

Interventions by the Province of Ontario

Date	Intervention	Status
March 12, 1981	A legal intervention was filed with the U.S. Environmental Protection Agency which requested the EPA to reject proposals from six states for a relaxation of emission limits governing 18 power plants in Ohio, Michigan, Illinois, West Virginia and Tennessee. This was expanded on March 27, 1981 to include two large power plants near Cleveland, Ohio.	As of April 1986, the status of the 20 SIPs was: Decision Pending 17 Approved 3
June 19, 1981	Ontario appeared at the U.S. EPA Section 126 Hearings held in Washington, D.C. in support of the States of New York and Pennsylvania in their petition concerning Interstate Pollution.	A legal suit has been filed by several States and environmental groups. EPA denied the petition in December 1984. The decision was appealed to the U.S. Circuit Court of Appeals and argued in December 1985. As of April 1986 judgement was reserved.
October 7, 1981	Before the Indiana Air Pollution Control Board to oppose an increase in SO_2 emissions for the Clifty Creek Generating Station to 7.52 lbs of SO_2 per million B.T.U.	Approved by the State of Indiana.
June 30, 1982	Before the Michigan Air Pollution Control Commission in opposition to the Detroit Edison request to delay bringing its Monroe Power Plant into compliance with the State of Michigan "one percent or equivalent sulphur in fuel" rule.	Denied by the State of Michigan.

Date	Intervention	Status
February 1983	A letter was submitted to the Indiana Air Pollution Control Board in opposition to the proposed sulphur dioxide emissions limit increase from 6.0 lbs of SO_2/MMBTU to 7.11 lbs for the Indianapolis Power and Light Generating Station in the Pike County Air Quality Basin.	Approved by the State of Indiana.
May 10, 1983	A letter was submitted to the U.S. E.P.A. in opposition to its proposed approval of a request by the Indiana Air Pollution Control Board to relax the state enforceable SO_2 emission limit for the Indiana-Michigan Electric Company Breed Plant from 6.0 lbs/MMBTU to 9.57 lbs/MMBTU.	Approved by the U.S. E.P.A.
November 28, 1983	Before the Michigan Air Pollution Control Commission in opposition to the Consumers Power Company request to delay bringing its J.G. Campbell and B.C. Cobb Power Plants into compliance with the Michigan "one percent or equivalent sulphur in fuel" rule.	Denied by the State of Michigan.
June 14, 1984	A letter was submitted to the Michigan Air Pollution Control Commission in opposition to the Consumers Power Company's second request to delay bringing its J.H. Campbell Power Plant into compliance with the Michigan "one percent or equivalent sulphur in fuel" rule.	Three year extension granted by the Commission in order to protect coal miners jobs at the Peabody Coal Company's Sunnyhill Mine.
October 24, 1985	Ontario requested and was granted intervenor status in an appeal by the U.S. E.P.A. and the States of Ohio and Kentucky against the Section 115 ruling by former Administrator Costle. Oral argument was heard May 15, 1986.	Judgement was reserved.

TASK #7 - PUBLIC RELATIONS INITIATIVES

Muskoka '85 Conference

The APIOS office and staff were involved in the planning and staging of the International Symposium on Acidic Precipitation which was held in Muskoka in September 1985. Over 700 scientists and environmentalists, representing 20 countries, attended and took part in the program of symposia and poster sessions. Some 500 papers were presented. APIOS related papers and posters are listed on pages 40-46.

The Muskoka Conference received strong attention from the news media. David Suzuki did a segment on the conference for his popular television program, The Nature of Things.

The Muskoka Conference was the largest and most successful event of its kind ever held anywhere in the world. It was jointly sponsored by the governments of Canada and the 10 provinces.

Countdown Acid Rain

Ontario's new Countdown Acid Rain program was introduced in December by Environment Minister Jim Bradley in a statement to the provincial legislature.

A press conference followed, with two-way video link-ups with news conferences simultaneously held in Washington, Ottawa, Sudbury, Sault Ste. Marie and Thunder Bay. It was the first time Ontario's teleconferencing system was used extensively for a major event.

Media kits on acid rain were handed out in Canada and the United States with the cooperation of External Affairs Canada, our embassy in Washington and 10 Canadian consulates throughout the U.S. By the end of the year, 20,000 kits were handed out to members of the news media, and environmental and special interest groups across the U.S.

The Countdown Acid Rain program resulted in new written materials to replace the "Case Against the Rain" booklet.

The film "Crisis in the Rain" has now reached an Ontario television-viewing audience of nearly 4.5 million. To date, more than 15 million have seen the film on the Public Broadcast System in the United States.

"Crisis in the Rain" has also been shown to community groups (with an estimated audience of over 110,000) and in schools (with an estimated audience of over 200,000 students).

To spread awareness of the acid rain problem south of the border, our embassy in Washington and 11 Canadian consulates throughout the United States have copies of the film for special showings.

SUMMARY

At the end of Fiscal Year 1985/86 the APIOS program has contributed to our understanding of the acid rain problem in Ontario and the following conclusions/milestones were reached:

- The Countdown Acid Rain program was announced which places regulations on the four major sources of SO_2 in Ontario. However, this will not be sufficient to achieve the target rate of 20 kg/ha·yr wet sulphate deposition which will continue to be exceeded.

- Nitrate contribution to acid loadings is comparable to sulphate contribution; however, in snowpacks nitrates may be more abundant.

- A working version of the eulerian long range transport model (ADOM) was installed at the CMC computer and evaluated with OSCAR 2 and PEPE/NEROS data.

- The Sarnia Oxidants Study findings indicated that although emissions from the Sarnia area lead to measurable increases in oxidant levels in southwestern Ontario, the major portion of the oxidant loading is attributable to long range transport from the United States.

- Lethal pH thresholds have been determined for the most sensitive stages of lake trout and brook trout. While Al does affect survival it appears that the H ion is the most likely toxic factor.

- A computerized method for identification, measurement and tabulation of zooplankton species was implemented.

- In the survey of 5,341 lakes, it was found that 4% were acidified (alkalinity ≤ 0 ueq·l^{-1}) and a further 14.8% were extremely sensitive (alkalinity >0 ueq·l^{-1} and <40 ueq·l^{-1}).

- Lichens and mosses are being investigated as air quality indicators. Sulphur content of lichens exhibits a south to north decrease in concentration.

- Results of simulated acid rain experiments with agricultural crops indicated that plant response is both species and cultivar dependent. In addition to the degree of acidity, duration and frequency of application affected the outcome.

- Fumigations with O_3 can reduce plant biomass.

- A study of spatial and seasonal variability of five soil sensitivity parameters was undertaken. Results indicated that most parameters were less variable in the summer.

- A study of maple decline in the Muskoka-Haliburton area determined that acidic deposition posed an additional stress to trees already suffering from an epidemic of tent caterpillar in the late '70's combined with several spring droughts, Armillaria mellea, tree age and site management.

- An investigation of the effects of forest, shrub and herb canopies indicated that most major ions (calcium, magnesium, potassium, sulphate and phosphate) are all leached from the canopy while nitrate and ammonia are retained. The physiological maturity of foliage as well as quantity of leaves influence the quality of precipitation reaching the soil.

- Soils appear to be major sinks for cadmium and lead while acidification releases zinc. Aluminum geochemistry is still being investigated.

- A feasibility study utilizing questionnaires and surveying lakefront cottage owners to determine presence of filamentous algae and odour producing algae (Chrysochromulina breviturrita), indicated that the cottagers' perception provided accurate reflection of the presence of problem densities of the algae.

APPENDIX I

INTERNATIONAL LRTAP PROJECTS - MOE CO-FUNDING

Project Title	Funding Agencies	Purpose
Acid Deposition and Oxidants Model (Super Model)	Environment Ontario Atmospheric Environment Service Umweltbundesamt (West Germany) Environment Quebec State of Minnesota State of New York Electric Power Research Institute	To improve predictions of source/receptor relationships, i.e., what areas are affected by what sources?
Dry Deposition Intercomparison Measurements	Environment Ontario Atmospheric Environment Service Illinois State Water Survey Nation Aeronautical Establishment U.S. Department of the Interior National Oceanic and Atmospheric Administration Environmental Protection Agency Argonne National Laboratory Oregon State University	To improve quality control and comparability of Canada/U.S. results.
Eulerian Model Field Verification	Environment Ontario Environment Canada U.S. E.P.A. Electric Power Research Institute	A field study is planned for the field verification of the eulerian model. A concept plan has been prepared and peer reviewed.

Project Title	Funding Agencies	Purpose
Rain Acidity Interlaboratory Study of Damage to Agricultural Crops	Environment Ontario Boyce Thompson Institute Argonne International Laboratory Corvallis Environmental Research Laboratory Oakridge National Laboratory Brookhaven National Laboratory	To measure the effects of different pH's on crops and to standardize techniques and procedures. Study has been completed. A similar study is being developed for exclusion canopy work.
Reversing Acidification in Norway - NIVA	Environment Ontario Norway Sweden Environment Canada United Kingdom	To test hypotheses on watershed sensitivity and to measure watershed response to reductions and increases in acid loadings. This issue has been recently raised by the U.S. E.P.A. as an impediment to designing a control program.
Unified Acid Deposition Data Base for Eastern North America	Environment Ontario Environment Canada National Atmospheric Deposition Program, U.S. Geological Survey Battelle Pacific Northwest Laboratory, U.S.	The unified data base should be useful for mathematical model evaluation and historical trend analysis

INTERNATIONAL LRTAP PROJECTS - MOE PARTICIPATION

Project Title	Participating Agencies	Purpose
Aluminum Biogeochemistry in Forested Watersheds	Electric Power Research Institute Environment Ontario Environment Canada United States West Germany Norway Sweden United Kingdom	To identify and quantify the release, transport and toxicity of aqueous aluminum in the natural environment. Aluminum is toxic to both fish and trees.
CAPTEX Data Analysis and Model Comparisons	Environment Ontario Environment Canada National Oceanic and Atmospheric Administration, U.S. Department of Energy, U.S.	A workshop on the Cross Apalachian Tracer Experiment (CAPTEX) was held November, 1985 to compare model predictions with ground-level tracer concentrations.
Free Aluminum in Surface Waters	Environment Ontario University of Maine	Agreement for interchange of samples for analysis to determine compatability of the methodologies.
Fisheries Loss Assessment Program	NAPAP Environment Ontario Ontario Ministry of Natural Resources EPRI Environment Canada	To assist NAPAP in the design of a program to assess fisheries loss in the U.S. related to acidic deposition.

Project Title	Participating Agencies	Purpose
Human Health Effects Related to Aquatic Effects of Acid Deposition	EPA Environment Ontario Various State Health Agencies	MOE has been invited to sit on a Committee of experts to determine the exact nature and extent of these human health effects.
Informal Calibrated Watershed Modelling Group	Environment Ontario Environment Canada United States Norway Sweden	To compare results and ideas on watershed studies. The work defines effects of acid rain and develops target loadings to prevent damage.
Interlaboratory Quality Assurance	Government and private laboratories in Canada and the U.S. (over 50 labs involved, including MOE)	To ensure the validity and compatibility of all data collected under LRT programs in North America.
Lake Acidification Mitigation Program	EPRI Clarkson College Environment Ontario	MOE has been requested to provide advice and information concerning lake liming projects.
National Surface Water Survey	EPA Environment Ontario Environment Canada	To characterize current water chemistry of lakes and streams in five U.S. Regions. MOE has been requested to assist in the development of the survey design.
Ontario/Germany Memorandum of Understanding	Ontario Federal Republic of Germany	To exchange information, scientists and modelling results to ensure that similar methodologies are used so that final results may be compared.

Project Title	Participating Agencies	Purpose
Ontario/Michigan Memorandum of Understanding	Ontario Michigan	To exchange information and perform joint studies to achieve and maintain a quality of environment to protect human health and the ecosystem where activities of one jurisdiction may affect the environment of the other.
Ontario/Minnesota Memorandum of Understanding	Ontario Minnesota	To exchange information on acid rain; to cooperate on specific projects (atmospheric modelling, RAIN - NIVA, aquatic effects in a medium deposition area).
Ontario/New York Memorandum of Understanding	Ontario New York	To exchange information on acid rain to improve understanding of acidification of the environment and establish coordinated courses of action in order to encourage abatement measures on an international basis.
Ontario/NADP Intercomparison Study - Ely, Minnesota	Ontario National Atmospheric Deposition Program	To improve comparability of data.

APPENDIX II

BIBLIOGRAPHY

PAPERS
PRESENTED AT MUSKOKA '85
INTERNATIONAL SYMPOSIUM ON ACIDIC PRECIPITATION

Booth, G.M., Hamilton, J.G. and L.A. Molot. 1985. The experimental lake neutralization project in Ontario, Canada.

Castel, A. and C. Griffith. 1985. Cost effective management of acid rain.

Dillon, P.J. 1985. Rates of alkalinity generation and loss in aquatic and terrestrial systems.

Hall, R.J. and N. Yan. 1985. Ecological effects of acidification on bacteria and invertebrates.

Jeffries, D.S., LaZerte, B. and R.A. Linthurst. 1985. Effect of acid deposition on the chemistry of aquatic ecosystems in eastern North America.

Keller, W., Pitblado, J.R. and N.I. Conroy. 1985. Water quality changes in Sudbury area lakes related to reduced smelter emissions.

Linzon, S.N. 1985. Activities and results of the terrestrial effects program: Acid Precipitation in Ontario Study (APIOS).

Linzon, S.N. and J. Skelly. 1985. Effects of gaseous pollutants on forests in eastern North America.

Mierle, G. 1985. Biological effects of acid deposition in eastern North America.

POSTERS
PRESENTED AT MUSKOKA '85
INTERNATIONAL SYMPOSIUM ON ACIDIC PRECIPITATION

Bardswick, W.S., Orr, D.B. and W.H. Chan. 1985. A quality assurance program and quality assessment of the acidic precipitation in Ontario study (APIOS) deposition monitoring networks.

Beggs, G.L., Gunn, J.M., Shuter, B.J. and P.E. Ihssen. 1985. The response of lake trout, brook trout, and smallmouth bass to surface water acidification in Ontario - A synthesis of bioassay and population data.

Brown, L.M., Wehr, J.D. and K.H. Nicholls. 1985. The bloom forming algal flagellate (Chrysochromulina breviturrita) and its relation to odour episodes in Muskoka area lakes: pH tolerance, nutrient and trace element requirements.

Case, J.W. 1985. Mapping acid precipitation deposition in Ontario using lichens and mosses as biological monitors.

Chan, W.H., Tang, A.J.S., Orr, D.B., Bardswick, W.S. and M.A. Lusis. 1985. An evaluation of instrumentation and sampling period for measurements of wet/dry deposition.

Clark, K. and R. Hall. 1985. Short-term acidification of streams and lakes as a result of snowmelt. X. Responses of amphibian eggs and larvae to increased acidity and elevated aluminum levels in ponds in central Ontario.

Clark, K.L. and B.D. LaZerte. 1985. Biological effects of acidification. IX. A laboratory study of the effects of aluminum and pH on amphibian eggs and tadpoles.

Dillon, P.J. and R. Girard. 1985. Chemical transformations. X. Changes in the chemistry of lakes near Sudbury, Ontario following reduction of SO_2 emissions.

Dillon, P.J. and B.D. LaZerte. 1985. Chemical transformations. III. Sulphate budgets for lakes and catchments in central Ontario.

Dillon, P.J. and B.D. LaZerte. 1985. Short-term acidification of streams and lakes as a result of snowmelt. IV. Quantification of the factors causing short-term acidification.

Dillon, P.J., Scheider, W.A. and R.A. Reid. 1985. Chemical transformations. II. Sources of alkalinity in lakes in central Ontario.

Dillon, P.J. and P.J. Scholer. 1985. Chemical transformations. XI. Trace metal accumulation in the sediments of lakes in central Ontario.

Muskoka '85 Posters (continued)

Dimma, M. 1985. Soil variability considerations in acidic precipitation effects studies.

Enyedi, A. and A. Kuja. 1985. Assessment of relative sensitivities of selected crop species and cultivars subjected to repeated acid rain treatment.

Gizyn, W.I., Barclay-Estrup, P. and W.D. McIlveen. 1985. Throughfall and stemflow chemistry under white pine exposed to varying acidic deposition loading.

Glooschenko, V., Blancher, P., Herskowitz, J., Fulthorpe, R. and S. Rang. 1985. The effects of lake acidification on the aquatic food chain and reproductive parameters of the eastern kingbird.

Gunn, J.M. and W. Keller. 1985. Effects of acidic meltwater on chemical conditions at nearshore spawning sites.

Gunn, J.M. and D.L.G. Noakes. 1985. Avoidance of low pH and elevated Al concentrations by lake char (Salvelinus namaycush) and brook char (S.fontinalis) yolk sac fry.

Hall, R.J. 1985. Short-term acidification of streams and lakes as a result of snowmelt. VII. Episodic snowmelt effects on chemistry and biology of Canadian shield aquatic ecosystems.

Hall, R.J. 1985. Short-term acidification of streams and lakes as a result of snowmelt. VIII. The effect of spring and fall experimental pH depressions on a stream ecosystem.

Hall, R.J. 1985. Short-term acidification of streams and lakes as a result of snowmelt. IX. Behavioural responses of stream macroinvertebrates to elevated H^+ and Al levels at Dorset and the Experimental Lakes Area (ELA), Ontario, Canada.

Hall, R.J. and J. Findeis. 1985. Biological effects of acidification. V. Recent changes in stream invertebrate communities: Is acidification the cause?

Holtze, K.E. and N.J. Hutchinson. 1985. Biological effects of acidification. XII. Comparative tolerance of six native Ontario fish species to hydrogen and aluminum concentration.

Hutchinson, N.J. and K.E. Holtze. 1985. Biological effects of acidification. XI. Factors influencing the acute lethality of hydrogen and Aluminum ion to lake and brook trout.

Hutchinson, N., Munro, J., Holtze, K. and T. Pawson. 1985. Biological effects of acidification. X. Utility of laboratory toxicity testing for describing in-situ responses of salmonids to acidification.

Muskoka '85 Posters (continued)

Jackson, M.B. 1985. Filamentous algae in Ontario softwater lakes.

Kuja, A., Jones, R. and A. Enyedi. 1985. A mobile rain exclusion canopy and gaseous pollutant reduction system to determine dose-response relationships between simulated acid precipitation and yield of field-grown soybean and radish crops.

LaZerte, B.D. 1985. Short-term acidification of streams and lakes as a result of snowmelt. V. Effects of springmelt on aluminum speciation in streams of Muskoka-Haliburton, Ontario.

LaZerte, B.D. 1985. Chemical transformations. VI. Forms of aqueous aluminum in acidified catchments of central Ontario: a methodological analysis.

LaZerte, B.D. and P.J. Dillon. 1985. Chemical transformations. IV. Relative importance of anthropogenic versus natural sources of acidity in lakes and streams of central Ontario.

LaZerte, B.D. and P.J. Dillon. 1985. Chemical transformation. V. Chemical transformations of stream and soil water flowing through Spagnum-conifer swamps of central Ontario.

Ley, B.E., Misra, P.K. and R. Bloxam. 1985. A lagrangian model study of meteorological variability in monthly and seasonal wet deposition of sulphur.

Ley, B.E., Misra, P.K. and S.Y. Wong. 1985. Evaluation of the MOE statistical model of long range transport employing puff trajectory statistics.

Lozano, F.C. and W.I. Gizyn. 1985. The influence of contrasting forest cover and soil properties on the chemical characteristics of acidic precipitation.

Lusis, M.A., Tang, A.J.S., Chan, W.H., Yap, D., Kurtz, J., Misra, P.K. and G. Ellenton. 1985. Sudbury smelter impact on atmospheric deposition of acidic substances in Ontario.

MacIsaac, H.J., Keller, W., Yan, N.D. and T.C. Hutchinson. 1985. Chemical and biological responses of an acidified, metal-contaminated lake following a reduction in acid input.

MacLean, J.A., Stewart, T., Hicks, F. and G.L. Beggs. 1985. A review of the evidence for effects of acidic deposition on Ontario fisheries.

Matuszek, J. and D. Wales. 1985. Fish species distribution in relation to lake acidity in Ontario.

Muskoka '85 Posters (continued)

McDonnell, J.H. and C.H. Taylor. 1985. Short-term acidification of streams and lakes as a result of snowmelt. III. The effect of ground and snowpack conditions on snowmelt-induced runoff.

McIlveen, W.D. and T. Spires. 1985. The role of forest shrub and herb canopies on precipitation chemistry.

McLaughlin, D.L., Linzon, S.N., Dimma, D.E. and W.D. McIlveen. 1985. Sugar maple decline in Ontario: Is acidic precipitation a contributing factor?

Mierle, G. and B. Clarke. 1985. Chemical transformations. VIII. Effect of acidification on the bioavailability of phosphorus in streams.

Munro, J.R., LaZerte, B.D. and T. Pawson. 1985. Short-term acidification of streams and lakes as a result of snowmelt. XI. Effects of snowmelt-induced changes in water chemistry on survival of lake and brook trout during in-situ exposures.

Munro, J.R. and T. Pawson. 1985. Short-term acidification of streams and lakes as a result of snowmelt. XII. In-situ assessment of early life-stage survival during short- and long-term exposures of 8 fish species to waters of varying pH and Al concentration.

Neville, C.M. 1985. Studies on the mechanism of toxicity of acid and aluminum to juvenile trout in a low ion environment.

Reid, N.W., Lam, L.H., Fung, C.S., Ley, B.E. and P.K. Misra. 1985. A lagrangian model with full gas and aqueous phase chemistry.

Rustad, S.N., Christophersen, N., Seip, H.M. and P.J. Dillon. 1985. Short-term acidification of streams and lakes as a result of snowmelt. VI. A model for streamwater chemistry in a tributary to Harp Lake during snowmelt.

Scheider, W.A., Locke, B.A. and A.C. Nicolls. 1985. Short-term acidification of streams and lakes as a result of snowmelt. I. Snowfall and snowpack chemistry.

Scheider, W.A. and L.A. Logan. 1985. Short-term acidification of streams and lakes as a result of snowmelt. II. Modelling snowmelt hydrology in Muskoka-Haliburton, Ontario.

Scheider, W.A., Logan, L.A. and L. Scott. 1985. Chemical transformations. I. Modelling of streamflow in small catchments in Muskoka-Haliburton, Ontario.

Muskoka '85 Posters (continued)

Scholer, P.J., Dillon, P.J. and B.D. LaZerte. 1985. Chemical transformations. IX. Relationships between water chemistry, surficial geology and other physical factors in lakes in Algonquin Park, Ontario.

Seip, H.M., Seip, R., Dillon, P.J. and E. DeGrosbois. 1985. Chemical transformations. VII. Modelling the hydrology and stream water chemistry of a small catchment in central Ontario.

Spires, A. 1985. Mapping the base status of the soils of northeastern Ontario.

Sutton, J., Deacon, K., Persson, G., Maki, L. and G. Ozburn. 1985. Sulphate and aluminum: Indicators of acid-stressed lakes in a low deposition area.

Tang, A.J.S., Chan, W.H., Chung, D.H.S. and M.A. Lusis. 1985. Spatial and temporal variability of precipitation concentration and wet deposition of acidic pollutants in Ontario.

Venkatram, V., Scire, J., Lurmann, F., Karamchandani, P., Lloyd, A.C., Yamartino, R., Lavery, T.F., Misra, P.K. and A.D. Christie. 1985. Some results from a comprehensive acid deposition model.

Wales, D. and G.L. Beggs. 1986. Fish species distribution in relation to lake acidity in Ontario.

Wher, J.D. and L.M. Brown. 1985. Selenium requirement of a bloom-forming planktonic alga from softwater and acidified lakes. Can. J. Fish. Aquat. Sci. 42:1783-1788.

Wehr, J.D., Brown, L.M. and K. O'Grady. 1985. Physiological ecology of the bloom-forming alga Chrysochromulina breviturrita Nich. (Pymnesiophyceae) from lakes influenced by acid precipitation. Can. J. Bot. 63:2231-2239.

Wong, S.K. and D. Yap. 1985. Overview of the Ontario acid rain emission inventory for Ontario and North America.

Yap, D. and J. Kurtz. 1985. Meteorological analyses of acidic precipitation in Ontario.

Yan, N.D. 1985. Biological effects of acidification. II. Evidence for direct influence of acidification on crustacean zooplankton communities of central Ontario lakes.

Yan, N.D. 1985. Biological effects of acidification. III. Long-term changes in the plankton of Clearwater Lake near Sudbury, Ontario: Have the communities responded to reduced acid inputs?

Muskoka '85 Posters (continued)

Yan, N.D. 1985. Biological effects of acidification. IV. Delayed recovery of zooplankton in neutralized lakes near Sudbury, Ontario.

Yan, N.D., Wile, I. and G. Miller. 1985. Biological effects of acidification. I. The influence of acidification and trace metal contamination on aquatic macrophyte communities of central Ontario lakes.

APPENDIX II

A.P.I.O.S. RELATED TECHNICAL REPORTS AND SUBMISSIONS

1986

Abundance of Chaoborus Larvae in Chub Lake: Sampling Methods and 1982 data. Lasenby, D.C., Morris, K. and N.D. Yan. Ont. Min. Env. Data Report DR 86/3.

Bryophyte Flora of Acid-Sensitive Lakes in South-Central Ontario: Description and Mechanisms of Sphagnum Invasion. Manville, G.C. and N.D. Yan. Ont. Min. Env. Tech. Rep. (in press).

Studies of Lakes and Watersheds in Muskoka-Haliburton, Ontario: Methodology (1976-1985). Locke, B.A. and L.D. Scott. Ont. Min. Env. Data Report DR 86/4.

User Manual for the Lab Information System (LIS), Dorset Research Centre. Nicolls, A., Locke, B.A. and S.A. McCormick. Ont. Min. Env. Data Report DR 86/2.

1985

Air Concentration and Dry Deposition Fields of Pollutants in Ontario, 1982. APIOS Report No. 001/85.

An Assessment of the Performance of the Daily Precipitation and Air Sampling Networks, July 1980 - December 1981. Acidic Precipitation in Ontario Study. Report ARB-100-85-AQM.

Annual Statistics of Concentration - Cumulative Ambient Air Monitoring Network, 1983. Acidic Precipitation in Ontario Study. Report ARB-089-85-AQM.

Annual Statistics of Concentration - Cumulative Ambient Air Monitoring Network, 1984. Acidic Precipitation in Ontario Study. Report ARB-237-85-AQM.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1984. Acidic Precipitation in Ontario Study. Report ARB-235-85-AQM.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Sites in Industrial/Urban Areas in Ontario, 1981 and 1982. APIOS Report No. 005/85.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1983. Acidic Precipitation in Ontario Study. Report ARB-087-85-AQM.

Annual Statistics of Concentration and Deposition - Daily Precipitation and Air Monitoring Networks. Acidic Precipitation in Ontario Study, 1983. Report ARB-109-85-AQM.

1985 (continued)

Annual Statistics of Concentration and Deposition - Daily Precipitation and Air Monitoring Network, 1984. Acidic Precipitation in Ontario Study. Report ARB-236-85-AQM.

Cumulative Ambient Air Concentration Listings. January 4, 1983 - January 3, 1984. Acidic Precipitation in Ontario Study. Report ARB-088-85-AQM.

Cumulative (28 Day) Precipitation Chemistry Listings of Sites in Industrial/Urban Areas in Ontario, September 1980 - January 1983. APIOS Report No. 003/85.

Cumulative (28 Day) Precipitation Chemistry Listings, January 4, 1983 - January 4, 1984. Acidic Precipitation in Ontario Study. Report ARB-063-85-AQM.

Daily Ambient Air Concentration Listings. Acidic Precipitation in Ontario Study. Report ARB-108-85-AQM.

The Morphometry and Geology of Plastic and Heney Lakes and Their Catchments. Girard, R., Reid, R.A. and W.R. Snyder. Ont. Min. Env. Data Report DR 85/1.

1983 Daily Precipitation Chemistry Listings. APIOS Report No. 004/85.

Ontario Soil Baseline Survey Analytical Data 1980/81. APIOS Report No. 002/85. Three Volumes.

Quality Assurance Management Programme for the Limnology Unit, Dorset Research Centre. Locke, B.S. Ont. Min. Env. Data Report DR 85/4.

Quality Assurance Manual. Deposition Monitoring Networks. Acidic Precipitation in Ontario Study. APIOS Report No. 006/85. February 1985.

The Sarnia Oxidants Study (June 27 - July 18, 1984): Analysis of the Air Quality and Meteorological Data. Lusis, M.A., Sahota, H. and D. Yap. Report ARB-124-85-AQM.

The Sarnia Oxidants Study (June 27 - July 18, 1984): Report on the Airborne Measurements. Sahota, H., Kiely, P. and M. Lusis. Report ARB-019-85-ARSP.

Sugar Maple Decline in Ontario. McLaughlin, D.L., Linzon, S.N., Dimma, D.E. and W.D. McIlveen. Report ARB-144-85-Phyto. APIOS 026/85.

Temperature and Oxygen Data for the Muskoka-Haliburton Study Lakes (1983-1984). Reid, R.A. and R. Girard. Ont. Min. Env. Data Report DR 85/2.

1985 (continued)

Temperature, Oxygen, pH and Dissolved Inorganic Carbon Data Summary for Eight Lakes in the Muskoka-Haliburton Study Area (1982-1984). Girard, R. and R.A. Reid. Ont. Min. Env. Data Report DR 85/3.

A Unified Wet Deposition Data Base for Eastern North America: Data Screening, Calculation Procedures, and Results for Sulphates and Nitrates (1980). Prepared by the Unified Deposition Database Committee (M. Lusis, Coordinator), 1985.

1984

An Analysis of the Effects of the Sudbury Emissions Sources on Wet and Dry Deposition in Ontario. Tang, A.J.S. and W.H. Chan. APIOS Report No. 011/84.

An Assessment of the Performance of the Cumulative Precipitation Monitoring Network - June, 1980 - December, 1981. Acidic Precipitation in Ontario Study. W.S. Bardswick. Report ARB-143-84-ARSP.

Annual Program Report - Fiscal Year 1982/1983. APIOS Report No. 001/84.

Annual Program Report - Fiscal Year 1983/1984. APIOS Report No. 010/84.

Annual Statistics of Concentration, Cumulative Ambient Air Monitoring Network, 1982. APIOS Report No. 015/84.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1982. APIOS Report No. 008/84.

Annual Statistics of Concentration and Deposition - Daily Precipitation and Air Monitoring Network, 1982. APIOS Report No. 009/84.

Cumulative Ambient Air Concentration Listings August 31, 1981 - January 4, 1983. APIOS Report No. 013/84.

Cumulative (28 Day) Precipitation Chemistry Listings - January 5, 1982 - January 4, 1983. APIOS Report No. 003/84.

The Economics of Acid Precipitation: A Review of Socio-Economic Methods to Assess Acid Deposition Effects. APIOS Report No. 006/84.

Emission Inventory of Ontario and Eastern North America during 1980-1983 with Emphasis on the Sudbury Shut-down Period. D. Yap. APIOS Report No. 016/84.

1984 (continued)

Examination of Monthly Wet Sulphate Deposition by a Lagrangian Model and its Application to Study the Effects of Source Control on Receptors. Ellenton, G. and P.K. Misra. APIOS Report No. 018/84.

Macrophyte Data from 46 Southern Ontario Soft Water Lakes of Varying pH. Hitchin, G.G., Wile, I., Miller, G.E. and N.D. Yan. Ont. Min. Env. Data Report DR 84/2.

Meteorological Studies to Quantify the Effects of Sudbury Emissions on Precipitation Quality and Air Quality During 1980-1983 with Emphasis on the Shut-down period. Kurtz, J. and D. Yap. APIOS Report No. 17/84.

1982 Daily Ambient Air Concentration Listings. APIOS Report No. 004/84.

1982 Daily Precipitation Chemistry Listings. APIOS Report No. 002/84.

An Overview of the Cumulative Wet/Dry Deposition Network. APIOS Report No. 007/84.

An Overview: The Cumulative Wet/Dry Deposition Network. Chan, W.H., Orr, D.B. and R.J. Vet. APIOS Report No. 005/84.

Physical and Chemical Data Summary for Twelve Selected Lakes in the Muskoka-Haliburton Area (1981-1983). Reid, R.A., Locke, B.A., Girard, G.E. and A.C. Nicolls. Ont. Min. Env. Data Report DR 84/1.

Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, 1982. APIOS Report No. 012/84.

Quality Assurance Plan - APIOS Deposition Monitoring Program.

Summary: Source Apportionment Analysis of Air and Precipitation Data to Determine Contribution of the Sudbury Smelters to Atmospheric Deposition in Ontario. Lusis, M.A. APIOS Report No. 019/84.

1983

Acid Sensitivity Survey of Lakes in Ontario. APIOS Report No. 001/83.

Acidic Precipitation in Ontario Study - Technical and Operating Manual, APIOS Deposition Monitoring Program. Bardswick, W.S. April 1983.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1981. Kirk, R.W. August 1983. APIOS Report No. 008/83.

1983 (continued)

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1981. Kirk, R.W. September 1983.

APIOS Daily Precipitation Chemistry Listings, July 15, 1980 - December 31, 1981. Revised Edition January 1983.

APIOS Monthly/28 Day Cumulative Precipitation Chemistry Listings, June 1980 - December 1981. March 1983.

Area Source Emission Inventory for Nitrogen Oxides in Ontario by Ontario Research Foundation for MOE. Final Report (Proposal No. p-4261/G). September 1983.

Crustacean Zooplankton Communities of the Muskoka-Haliburton Study Lakes: Methods and 1976-1979 Data. Hitchin, G.G. and N.D. Yan. Ont. Min. Env. Data Report DR 83/9.

Daily Ambient Air Concentration Listings, July 25, 1980 - December 31, 1981. May 1983.

Depth and Volume of Strata in the Muskoka-Haliburton Study Lakes (1976-1982). Girard, R., Locke, B.A. and R.A. Reid. Ont. Min. Env. Data Report DR 83/10.

Geology and Geochemistry of the Muskoka-Haliburton Study Area. Jeffries, D.S. and W.R. Snyder. Ont. Min. Env. Data Report DR 83/2.

Hydrological Data for Lakes and Watersheds in the Muskoka-Haliburton Study Area (1976-1980). Scheider, W.A., Cox, C.M. and L.D. Scott. Ont. Min. Env. Data Report DR 83/6.

The Macrophyte Flora of 46 Acidified and Acid Sensitive Soft Water Lakes in Ontario. Wile, I. and G. Miller. Ont. Min. Env. Tech. Rep.

Meteorological Analysis of Precipitation Event Sampling Data (July 1980 - December 1981). Kurtz, J. June 1983.

Morphometry of the Muskoka-Haliburton Study Lakes. Nicholls, A., Reid, R. and R. Girard. Ont. Min. Env. Data Report DR 83/8.

1981 Summary Statistics of Observed Concentration and Deposition: Daily Precipitation Monitoring Network. Kirk, R.W. and W.H. Chan. June 1983.

Oxygen Profiles on the Muskoka-Haliburton Study Lakes (1976-1982). Reid, R.A., Girard R. and B.A. Locke. Ont. Min. Env. Data Report DR 83/5.

1983 (continued)

A Performance and Systems Audit of the Acidic Precipitation in Ontario Study Monitoring Networks, Volume 1 and Volume 2 (Appendices). Submitted by Concord Scientific Corporation. ARB-69-83-ARSP. 1983.

Phytoplankton of Lakes in the Muskoka-Haliburton Area. Nakomoto, L., Heintsch L. and A. Nicholls. Ont. Min. Env. Data Report DR 83/8.

Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, September 1980 to December 1981. Chan, W.H., Tang, A.J.S. and M.A. Lusis. June 1983.

A Preliminary Study for the Compilation of a VOC Emission Inventory for the Province of Ontario by Concord Scientific Corporation for MOE. Final Report CSC 110.260. June 1983.

Procedures Manual - Terrestrial Effects. Griffin H.D. (Ed.). APIOS Report No. 007/83.

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Consumers Power Company Request to Delay Bringing its J.H. Campbell and B.C. Cobb Power Plants into Compliance with the Michigan "One Percent or Equivalent Sulphur in Fuel" Rule. Grand Haven, Michigan. November 28, 1983.

Sediment Chemistry of Lakes in the Muskoka-Haliburton Study Area. Smith, P.J. Ont. Min. Env. Data Report DR 83/7.

Studies of Lakes and Streams: Pukaskwa National Park. Sutton, J., Maki, L., Deacon, K.J. and G.W. Ozburn. API 003/83.

Studies of Lakes and Watersheds in Muskoka-Haliburton, Ontario: Methodology (1976-1982). Scheider, W.A., Reid, R.A., Locke, B. and L.D. Scott. Ont. Min. Env. Data Report DR 83/1.

Temperature Profiles on the Muskoka-Haliburton Study Lakes (1976-1982). Reid, R.A., Locke, B. and R. Girard. Ont. Min. Env. Data Report DR 83/4.

Total Phosphorus and Major Ion Mass Balances for Lakes in the Muskoka-Haliburton Study Area (1976-1980). Dillon, P.J. and W.A. Scheider. Ont. Min. Env. Data Report DR 83/11.

Water Quality-Crustacean Plankton Relationships in Northeastern Ontario Lakes. Keller, W. AND J.R. Pitblado. API 002/83.

1982

Acid Sensitivity Survey of Lakes in Ontario. APIOS 003/82. Summer 1982.

1982 (continued)

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. Reprint with Supplementary Insert - Summer 1982.

Daily Precipitation Chemistry Listings and Statistical Summaries July 15, 1980 - December 31, 1981. APIOS 001/82.

The Economics of Acid Precipitation: Ontario's Socio-economic Research Program. API 007/82. December 1982.

Experimental Neutralization of a Small, Seasonally Acidic Stream Using Crushed Limestone. API 004/82. Summer 1982.

Lagrangian Model of the Long Range Transport of Sulphur Oxides. API 008/82. Fall 1982.

Monitoring of Lake Superior Tributaries, 1980-1981. API 009/82. Fall 1982.

An Overview: The Cumulative Wet/Dry Deposition Network. December 1982.

An Overview: The Event Wet/Dry Deposition Network. API 002/82. Summer 1982.

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Detroit Edison Request to Delay Bringing its Monroe Power Plant into Compliance with the State of Michigan "1% or Equivalent Sulphur in Fuel" Rule. Monroe, Michigan. June 30, 1982.

Report of the Ontario/Canada Task Force for the Development and Evaluation of Air Pollution Abatement Options for Inco Limited and Falconbridge Nickel Mines, Limited in the Regional Municipality of Sudbury, Ontario. December 21, 1982.

Standard Methods for National Wet-only Precipitation Sampling and Chemistry Analysis. McQuaker, N.R., Kluckner, P.D., Torneby, J.E., Sorba, S.E., Chan, W.H. and M.E. Still., A Joint Report with the Federal and Other Provincial Governments. 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Muskoka-Haliburton Area of Ontario, 1980. API 006/82. Fall 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Sudbury Area of Ontario, 1981. API 005/82. Fall 1982.

1981

Acid Sensitivity Survey of Lakes in Ontario. API 002/81. March 1981.

1981 (continued)

An Annotated Bibliography: Terrestrial Effects of Acidic Precipitation. APIOS 003/81. July 1981.

Chemical, Microbiological and Physical Interactions of Acidic Precipitation Within a Lake and its Drainage Basin. Flett, R.J. API 004/81. July 1981.

An Intercomparison Study of Three Precipitation Sampling Networks in Ontario - APIOS, CANSAP and GLPN. Vet, R.J., Chan, W.H. and M.A. Lusis. Report No. ARB-002-91-ARSP. September 1981.

Lakewide Odours in Ontario and New Hampshire Caused by Chrysochromulina breviturrita Nich. (Pymnesiophyceae). API 001/81. 1981.

Ontario Ministry of the Environment. Studies of Lakes and Watersheds Near Sudbury, Ontario: Final Limnology Report of the Sudbury Environmental Study: Volume I.

Ontario Ministry of the Environment. Studies of Lakes and Watersheds Near Sudbury, Ontario: Final Limnology Report of the Sudbury Environmental Study: Volume II. Appendices.

The Province of Ontario. Presentation to the Air Pollution Control Board of the State of Indiana in Opposition to the Indiana-Kentucky Electric Generating Station Petition to Operate With an Increase in its Sulphur Dioxide Emissions to 7.52 pounds of SO_2 per Million BTU's of Heat Input. Indianapolis, Indiana. October 7, 1981.

The Province of Ontario. A Submission to the United States Environmental Protection Agency Hearing on Interstate Pollution Abatement. Washington, D.C. June 19, 1981.

The Province of Ontario. A Submission to the United States Environmental Protection Agency on Interstate Pollution Abatement. December 1981. Docket No. A-81-09.

The Province of Ontario. A Submission to the United States Environmental Protection Agency Opposing Relaxation of SO_2 Emission Limits in state Implementation Plans and Urging Enforcement. March 12, 1981. Expanded March 27, 1981.

The Seasonal Dependence of Atmospheric Deposition and Chemical Transformation Rates for Sulphur and Nitrogen Compounds. Lusis, M.A. and L. Shenfeld. Report No. ARB-018-ARSP. 1981.

Simple Nitrogen Oxides Chemistry for Incorporation into Long Range Mathematical Models. Prepared by Concord Scientific Corporation. Report No. ARB-008-81-ARSP. February 1981.

1980

Acidic Precipitation in South-Central Ontario: Analysis of Source Regions Using Air Parcel Trajectories. Kurtz, J. and W. Scheider. MOE Report, May 1980.

Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of Inco Ltd. in Sudbury. Scheider, W.A., Jeffries, D.S. and P.J. Dillon. May 1980.

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. October 1980.

Precipitation Sampler Comparative Study. Report Number ARB-007-81-ARSP. May 1980.

1979

Ontario Ministry of the Environment. Determination of the Susceptibility to Acidification of Poorly Buffered Surface Waters. Ont. Min. Env. Tech. Rep., 21 p.

Survival of Rainbow Trout, Salmo gairdneri in Submerged Enclosures in Lakes Treated with Neutralizing Agents Near Sudbury, Ontario. Yan, N.D., Girard, R.E. and C.L. Lafrance. Ont. Min. Env. Tech. Rep. LTS 79-2, 29 p.

1978

Acid Precipitation: A Review. Yan, N.D. Tech. Rep. EE-9. 35 p.

A.P.I.O.S. RELATED PUBLICATIONS/PAPERS

Bisessar, S., Palmer, K.T., Kuja, A.L. and S.N. Linzon. (1984). Influence of Simulated Acidic Rain on Bacterial Speck of Tomato. Journal of Environmental Quality, Vol. 13, pp. 18-22.

Chan, W.H. 1982. Quality Assurance - Monitoring of Wet Deposition. Presented at the Symposium on Monitoring and Assessment of Airborne Pollutants with Special Emphasis on Long-Range Transport and Deposition of Acidic Materials, National Research Council of Canada, Ottawa, Ontario, August 30 - September 1, 1982.

Chan, W.H. and M.A. Lusis. 1985. Post-Superstack Sudbury Smelter Emissions and Their Fate in the Atmosphere: An Overview of the Sudbury Environmental Study. Water, Air and Soil Pollution 26:43-58.

Chan, W.H. 1982. Sudbury Environmental Study - Atmospheric Research Program. Report ARB-27-82-ARSP.

Chan, W.H.and M.A. Lusis. 1983. Sudbury Smelter Emissions and Their Fate in the Atmosphere. Submitted to Environmental Science and Technology as a feature article.

Chan, W.H. and M.A. Lusis. 1986. Smelting Operations and Trace Metals in Air and Precipitation in the Sudbury Basin in "Toxic Metals in the Air". Nriagu, J.O. and C.I. Davison, (Eds.), John Wiley and Sons.

Chan, W.H., Lusis, M.A., Stevens, R.D.S. and R.J. Vet. 1984. A Precipitation Sampler Intercomparison. Water, Air and Soil Pollution 23:1-13.

Chan, W.H., Rc, C.U., Vet, R.J., Tang, A.J.S. and M.A. Lusis. 1983. Precipitation Scavenging and Dry Deposition of Pollutants from the Inco Nickel Smelter in Sudbury. Proceedings of the 4th International Conference on Precipitation Scavenging, Dry Deposition and Resuspension, G. Slinn, (Ed.), Elsevier Science Publishing Co. Inc., 1983.

Chan, W.H., Tang, A.J. and M.A. Lusis. 1983. Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, 1981. Report ARB-61-83-ARSP.

Chan, W.H., Vet, R.J., Lusis, M.A. and G.B. Skelton. 1983. Airborne Particulate Size Distribution Measurements in Nickel Smelter Plumes. Atmospheric Environment 17:1173-1181.

Chan, W.H., Vet, R.J., Lusis, M.A. and G.B. Skelton. 1982. Size Distribution and Emission Rate Measurements of Particulates in the Inco 381 M Chimney and Iron Ore Recovery Plant Stack Plumes, 1979-80. Report ARB-TDA-62-80.

Chan, W.H., Vet, R.J., Ro, C.U. and M.A. Lusis. 1982. Impact of the Inco Nickel Smelter Emissions on Precipitation Quality in the Sudbury Area. Atmospheric Environment 16:801-814.

Chan, W.H., Vet, R.J., Ro, C.U., Tang, A.J.S. and M.A. Lusis. 1982. An Analysis of the Impact of Smelter Emissions on Atmospheric Dry Deposition in the Sudbury Area: Sudbury Environmental Study Airborne Particulate Matter Network Results. Report ARB-012-81-ARSP.

Chan, W.H., Vet, R.J., Ro, C.U., Tang, A.J.S. and M.A. Lusis. 1982. An Analysis of the Impact of Smelter Emissions on Precipitation Quality and Wet Deposition in the Sudbury Area: Sudbury Environmental Study Event Precipitation Network Results. Report ARB-05-82-ARSP.

Chan, W.H., Vet, R.J., Ro, C.U., Tang, A.J.S. and M.A. Lusis. 1984. Impact of Inco Smelter Emissions on Wet and Dry Deposition in the Sudbury Area. Atmospheric Environment 18:1001-1008.

Chan, W.H., Vet, R.J., Ro, C.U., Tang, A.J.S. and M.A. Lusis. 1984. Impact of Smelting Activities on Long-Term Precipitation Quality and Wet Deposition Fields in the Sudbury Basin. Atmospheric Environment 18:1175-1188.

Chan, W.H., Vet, R.J., Ro, C.U., Tang, A.J.S. and M.A. Lusis. 1982. Precipitation Quality and Wet Deposition in the Sudbury Basin: Sudbury Environmental Study Cumulative Precipitation Network Results. Report ARB-04-82-ARSP.

Chan, W.H., Vet, R.J., Skelton, G.B. and M.A. Lusis. 1982. Size Distribution and Emission Rate Measurements of Particulates in the 93 M Falconbridge Smelter Stack Plume, 1979. Report ARB-TDA-57-80.

Clark, K.L. and R.J. Hall. 1985. Effects of Elevated Hydrogen Ion and Aluminum on Survival of Amphibian Embryos and Larvae. Can. J. Zool. 63:116-123.

Clark, K.L. and B. LaZerte. 1985. A Laboratory Study of the Effects of Aluminum and pH on Amphibian Eggs and Tadpoles. Can. J. Fish. Aquat. Sci. 42:1544-1551.

Conroy, N., Hawley, K., Keller, W. and C. Lafrance. 1976. Influences of the Atmosphere on Lakes in the Sudbury Area. Proc. First Spec. Symp. on Atmospheric Assoc. Great Lakes Res. 2:146-165.

Conroy, N., Hawley, K. and W. Keller. 1978. Extensive Monitoring of Lakes in the Greater Sudbury Area, 1974-76. Ontario Ministry of the Environment Technical Report.

Conroy, N., Jeffries, D.S. and J.R. Kramer. 1974. Acid Shield Lakes in the Sudbury, Ontario Region. Proceedings of 9th Canadian Symposium on Water Pollution Research in Canada No. 9, pp. 45-61.

Conroy, N., and W. Keller. 1976. Geological Factors Affecting Biological Activity in Precambrian Shield Lakes. Canadian Mineral 14:62-72.

Craig, G.R. and W.F. Baksi. 1977. The Effects of Depressed pH on Flagfish Reproduction, Growth and Survival. Wat. Res. 11:621-626.

deGrosbois, E., Dillon, P.J., Seip, H.M., and H. Seip. 1986. Modelling Hydrology and Sulphate Concentration in Small Catchments in Central Ontario. Wat. Air Soil Pollut. (in press).

Dillon, P.J. 1984. The Use of Mass Balances and Mass Balance Models for Quantification of the Effects of Anthropogenic Activities on Lakes Near Sudbury, Ontario. pp. 283-347, in Environmental Impacts of Smelters, J. Nriagu, (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Dillon, P.J. 1983. Chemical Alterations of Surface Waters by Acidic Deposition in Canada. Wat. Qual. Bull. 8:127-132.

Dillon, P.J. and R.D. Evans. 1982. Whole-lake Lead Burdens in Sediments of Lakes in Southern Ontario, Canada. Hydrobiol. 91:121-130.

Dillon, P.J., Jeffries, D.S. and W.A. Scheider. 1982. The Use of Calibrated Lakes and Watersheds for Estimating Atmospheric Deposition Near a Large Point Source. Wat. Air Soil Pollut. 18:241-258.

Dillon, P.J., Jeffries, D.S., Scheider, W.A. and N.D. Yan. 1980. Some Aspects of Acidification in Southern Ontario. p. 212-213, in "Proc. Int. Conf. Ecol. Impact Acid Precip.", Drablos, D. and A. Tollan (Eds.), Norway.

Dillon, P.J., Jeffries, D.S., Snyder, W., Reid, R., Yan, N.D., Evans, D., Moss, J. and W.A. Scheider. 1978. Acidic Precipitation in South-Central Ontario: Recent Observations. J. Fish. Res. Board. Can. 35:809-815.

Dillon, P.J., Reid, R.A. and R. Girard. 1986. Changes in the Chemistry of Lakes Following Reductions of SO_2 Emissions. Wat. Air Soil Pollut. (in press).

Dillon, P.J. and W.A. Scheider. 1984. Modelling the Reacidification Rates of Neutralized Lakes Near Sudbury, Ontario. pp. 121-154, in Modelling of Total Acid Precipitation Impacts, Schnoor, J.L. (Ed.), Acid Precipitation Series, Volume 9, Ann Arbor Science.

Dillon, P.J. Scholer, P.J. and H.E. Evans. 1985. Lead-210 Fluxes in Acidified Lakes. J. Environ. Geol. Wat. Sci. (in press).

Dillon, P.J. and P.J. Smith. 1984. Trace Metal and Nutrient Accumulation in the Sediments of Lakes Near Sudbury, Ontario. pp. 375-426, in Environmental Impact of Smelters, Nriagu, J., (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Dillon, P.J., Yan, N.D. and H.H. Harvey. 1984. Acidic Precipitation: Effects on Aquatic Ecosystems. CRC Critical Reviews in Environmental Control 13:167-194.

Dillon, P.J., Yan, N.D., Scheider, W.A. and N. Conroy. 1979. Acidic Lakes in Ontario, Canada: Characterization, Extent and Responses to Base and Nutrient Additions. Arch. Hydrob. Beih, Ergebn. Limnol. 13:317-336.

Ellenton, G., Ley, B.E. and P.K. Misra. 1985. A Trajectory Puff Model of Sulphur Transport for Eastern North America. Atmospheric Environment 19:727-737.

Ellenton, G., Ley, B.E. and P.K. Misra. 1983. Treating Exponential Mass Decay When Wet Scavenging Varies Discreetly Within an Expanding Gaussian Dispersed Puff. The Meteorology of Acid Deposition, Samson, P.J., (Ed.), Proceedings of an APCA Specialty Conference, pp. 528-536.

Evans, H.E., Lasenby, D.C. and P.J. Dillon. 1986. The Effect of Core Compression on the Measurement of Zinc Concentrations and Anthropogenic Burdens in Lake Sediments. Hydrobiol. 132:185-192.

Evans, H.E., Smith, P.J. and P.J. Dillon. 1983. Anthropogenic Zinc and Cadium Burdens in Sediments of Selected Southern Ontario Lakes. Can. J. Fish. Aquat. Sci. 40:570-579.

Evans, R.D. and P.J. Dillon. 1982. Historical Changes in Anthropogenic Lead Fallout in Southern Ontario, Canada. Hydrobiol. 91:131-137

Galloway, J.N. and P.J. Dillon. 1983. Effects of Acidic Deposition: The Importance of Nitrogen. Ecological Effects of Acid Deposition. Nat. Swedish Envir. Protection Bd. - Report PM 1636:145-160.

Glass, G.E. and T.G. Brydges. 1982. Problem Complexity in Predicting Impacts from Altered Precipitation Chemistry. In Acid Rain/Fisheries, Johnson, R.E., (Ed.), American Fisheries Society, Bethesda, Md., pp. 265-286.

Glass, G.E., Leonard, E.N., Chan, W.H. and D.B. Orr. 1986. Airborne Mercury in Precipitation in the Lake Superior Region. Journal of the International Association for Great Lakes Research 12:37-51.

Gunn, J.M. 1986. Behaviour and Ecology of Salmonid Fishes Exposed to Episodic pH Depressions. Env. Biol. Fish. (in press).

Gunn, J.M. and W. Keller. 1985. Effects of Ice and Snow Cover on the Chemistry of Nearshore Lake Water During Spring Melt. Annals of Glaciology (in press).

Gunn, J.M. and W. Keller. 1981. Emergence and Survival of Lake Trout (Salvelinus namaycush) and Brook Trout (S. fontinalis) from Artificial Substrates in an Acid Lake. Ontario Fisheries Technical Report Series, 1, Toronto.

Gunn, J.M. and W. Keller. 1980. Enhancement of the Survival of Rainbow Trout (Salmo gairdneri) Eggs and Fry in an Acid Lake through Incubation in Limestone. Can. J. Fish. Aquat. Sci. 37:1522-1530.

Gunn, J.M. and W. Keller. 1984. In Situ Manipulation of Water Chemistry Using Crushed Limestone and Observed Effects on Fish. Fisheries 9:19-24.

Gunn, J.M. and W. Keller. 1984. Spawning Site Water Chemistry and Lake Trout (Salvelinus namaycush) Sac Fry Survival During Spring Snowmelt. Can. J. Fish. Aquat. Sci. 42:319-329.

Harvey, H.H., Pierce, R.C., Dillon, P.J., Kramer, J.P. and D.M. Whelpdale. 1981. Acidification in the Canadian Aquatic Environment. Publ. NRCC No. 18475 of the Environment Secretariat, National Research Council, Canada.

Hendry, G.R., Yan, N.D. and K.J. Baumgartner. 1980. Responses of Freshwater Plants and Invertebrates to Acidification. pp. 457-466. In "Restoration of Lakes and Inland Waters". Proc. Symp. 8-12 September 1980. Portland, Maine, U.S.A. EPA 440 15-81-010.

Jeffries, D.S. 1984. Atmospheric Deposition of Pollutants in the Sudbury Area. pp. 117-154, in Environmental Impacts of Smelters, Nriagu, J., (Ed.), Advances in Environmental Impacts of Science Series, John Wiley and Sons, Inc.

Jeffries, D.S., Cox, C.M. and P.J. Dillon. 1979. Depression of pH in Lakes and Streams in Central Ontario During Snowmelt. J. Fish. Res. Board. Can. 36:640-646.

Jeffries, D.S., Scheider, W.A. and W.R. Snyder. 1984. Geochemical Interactions of Watersheds with Precipitation in Areas Affected by Smelter Emissions Near Sudbury, Ontario. pp. 195-241, in Environmental Impacts of Smelters, Nriagu, J., (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Jeffries, D.S. and W.R. Snyder. 1981. Atmospheric Deposition of Heavy Metals in Central Ontario. Wat. Air Soil Pollut. 15:127-152.

Jeffries, D.S. and W.R. Snyder. 1981. Variations in Chemical Composition of the Snowpack and Associated Melt-waters in Central Ontario. Proc. 38th Eastern Snow Conference, New York.

Jeffries, D.S., Snyder, W.R., Scheider, W.A. and M. Kirby. 1978. Small-Scale Variations in Precipitation Loading Near Dorset, Ontario. Wat. Poll. Res. Can. 13:73-84.

Jeffries, D.S., and A.P. Zimmerman. 1980. Comments on the Analysis and Sampling of Low Conductivity Natural Waters for Alkalinity. Can. J. Fish. Aquat. Sci. 37:901-902.

Keller, W. 1978. Limnological Observations on the Aurora Trout Lakes. Ontario Ministry of the Environment Technical Report. 49 pages.

Keller, W. 1981. Planktonic Crustacea in Lakes in the Greater Sudbury Area. Ontario Ministry of the Environment Technical Report. 33 pages plus appendices.

Keller, W. 1983. Spring pH and Alkalinity Depressions in Lake Superior Tributaries. J. Great Lakes Res. 9:425-429.

Keller, W., Gunn, J. and N. Conroy. 1980. Acidification Impacts on Lakes in the Sudbury, Ontario, Canada Area. Proc. Int. Conf. on the Ecological Impact of Acid Precipitation, Sandefjord, Norway. pp 228-229.

Keller, W. and J.R. Pitblado. 1984. Crustacean Plankton in Northeastern Ontario Lakes Subjected to Acidic Deposition. Wat. Air Soil Poll. 23:271-291.

Kuja, A.L. and A.J. Enyedi. 1983. Effect of Simulated Acid Rain on Agricultural Crops. Proceedings Agrometeorological Workshop, University of Guelph, pp. 82-83.

Kurtz, J. and W.A. Scheider. 1981. An Analysis of Acidic Precipitation in South-Central Ontario Using Air Parcel Trajectories. Atm. Environ. 15:1111-1116.

Kurtz, J., Tang, A.J., Kirk, R.W. and W.H. Chan. 1983. Analysis of an Acidic Deposition Episode at Dorset, Ontario. Accepted for publication in Atmospheric Environment.

LaZerte, B.D. 1986. Metals and Acidification: An Overview. Wat. Air Soil Pollut. (in press).

LaZerte, B.D. 1984. Forms of Aqueous Aluminum in Acidified Catchments of Central Ontario: A Methodological Analysis. Can. J. Fish. Aquat. Sci. 41:766-776.

LaZerte, B.D. and P.J. Dillon. 1984. Relative Importance of Anthropogenic Versus Natural Sources of Acidity in Lakes and Streams of Central Ontario. Can. J. Fish. Aquat. Sci. 41:1664-1677.

Linzon, S.N., Pearson, R.G., Gizyn, W.I. and M.A. Griffith. 1981. Terrestrial Effects of Long Range Pollutants on Crops and Soils. Proceedings Air Pollution Control Association. Ontario and Quebec Sections. Joint Meeting on Acid Deposition, Montreal, Quebec, 17 pp.

Linzon, S.N. and P.J. Temple. 1980. Soil Resampling and pH Measurements After an 18-Year Period in Ontario. Proc. In Conf. on the Ecological Impact of Acid Precipitation, Sandefjord, Norway, pp. 176-177.

Lusis, M.A. 1982. Measurement Techniques for Acidic Airborne Constituents. Presentation at the Symposium on Monitoring and Assessment of Airborne Pollutants with Special Emphasis on Long-Range Transport and Deposition of Acidic Materials, National Research Council of Canada, Ottawa, Ontario, August 30 - September 1, 1982.

Lusis, M.A., Chan, W.H., Tang, A.J. and N.D. Johnson. 1983. Scavenging Rates of Sulphur and Trace Metals from a Smelter Plume. Proceedings, 4th International Conference on Precipitation Scavenging, Dry Deposition and Resuspension. Slinn, E.G. (Ed.), Elsevier Science Publishing Co. Inc.

Lusis, M.A., Chan, W.H., Tang, A.J. and R.W. Kirk. 1983. Wet and Dry Deposition of Sulphur and Nitrogen Compounds on a Regional Scale: Results from the Ontario Network for 1982. CACGP Symposium on Tropospheric Chemistry, August 28 - September 3, Oxford.

Lusis, M.A. and L. Shenfeld. 1981. The Seasonal Dependence of Atmospheric Deposition and Chemical Transformation Rates for Sulphur and Nitrogen Compounds. Report No. ARB-08-ARSP.

MacIsaac, H.J., Keller, W., Hutchinson, T.C. and N.D. Yan. 1986. Natural Changes in Planktonic Rotifera of a Small Acid Lake near Sudbury, Ontario Following Water Quality Improvements. Wat. Air Soil Pollut. (in press).

Matuszek, J.E. 1986. Fish species richness in relation to pH in Ontario Lakes. J. Fish. Aquat. Sci. (in press).

McBean, E.A. and Associates Ltd. 1983. Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. 1983. Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Appendix I: "Mathematical Model Documentation of DATAGEN". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. 1983. Linear Programming Screening model for Development and Evaluation of acid Rain Abatement Strategies. Appendix II: "Development of SO_2 Emission Control Costs". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McBean, E.A. and Associates Ltd. 1983. Linear Programming Screening Model for Development and Evaluation of Acid Rain Abatement Strategies. Appendix III: "Canadian Source Inventory". Toronto: Policy and Planning Branch, Ontario Ministry of the Environment.

McLaughlin, D.L., Linzon, S.N., Dimma, D.E. and W.D. McIlveen. 1985. Sugar Maple Decline in Ontario. Interim Report, 18 pp.

McQuaker, N.R., Kluckner, P.D., Torneby, J.E., Sorbara, S.E., Chan, W.H. and M.E. Still. 1982. Standard Methods for National Wet-Only Precipitation Sampling and Chemical Analysis. A Joint Report with the Federal and other Provincial Governments.

Mierle, G. 1985. Kinetics of Phosphate Transport by Synechococcus leopoliensis: Evidence for Diffusion Limitation of Phosphate Uptake. J. Phycol. 21:177-181.

Mierle, G. 1985. A Method for Estimating the Diffusion of Resistance of the Unstirred Layer of Microorganisms. Biochim. Biophys. Acta. 812:827-834.

Mierle, G. 1985. The Effect of Cell Size and Shape in the Resistance of Unstirred Layers to Solute Diffusion. Biochimica et Biophysica Acta. 812:835-839.

Mierle, G., Clark, K. and R. France. 1986. The Impact of Acidification on Aquatic Biota in North America: A Comparison of Field and Laboratory Results. Wat. Air Soil Pollut. (in press).

Millan, M.M., Barton, S.C., Johnson, N.D., Weisman, B., Lusis, M.A., Chan, W. and R. Vet. 1982. Rain Scavenging from Tall Stack Plumes: A New Experimental Approach. Atmospheric Environment 16:2709-2714.

Miller, G.E., Wile, I. and G. Hitchin. 1983. Patterns of Accumulation of Selected Metals in Members of the Soft-water Macrophyte Flora of Central Ontario Lakes. Aquat. Botany 15:53-64.

Minns, C.K. 1986. Analysis of the Ontario Lake Inventory Data Base I and a Model of Biases in Lake Selection and II Fish Species Community Structure in Ontario Lakes. Ont. Fish. Tech. Rep. Sci. (in press).

Misra, P.K., Chan, W.H., Chung, D. and A.J.S. Tang. 1985. Scavenging Ratios of Acidic Pollutants and Their Use in Long Range Transport Models. Atmospheric Environment 19:1741-45.

Nicholls, K.H. 1978. Chrysochromulina breviturrita sp. nov., a New Freshwater Member of the Prymnesiophyceae. J. Phycol. 14:499-505.

Nicholls, K.H., Beaver, J.L. and R.H. Estabrook. 1982. Lakewide Odours in Ontario and New Hampshire Associated with Chrysochromulina breviturrita Nich. (Prymnesiophyceae). Hydrobiol.

Nicholls, K.H. and C. Cox. 1978. Atmospheric Nitrogen and Phosphorus Loading to Harp Lake, Ontario, Canada. Water Resources Res. 14:589-592.

Pitblado, J.R. and W. Keller. 1984. Data Report - Monitoring of Northeastern Ontario Lakes, 1981-83. Ontario Ministry of the Environment Technical Report. 9 pages plus appendices.

Pitblado, J.R., Keller, W. and N. Conroy. 1980. A Classification and Description of some Northeastern Ontario Lakes Influenced by Acid Precipitation. J. Great Lakes Res. 6:247-257.

Ruby, S.M., Aezel, J. and G.R. Craig. 1977. The Effects of Depressed pH on Oogenesis in Flagfish Jordanella floridae. Wat. Res. 11:757-762.

Ruby, S.M., Aezel, J. and G.R. Craig. 1978. The Effects of Depressed pH on Spermatogenesis in Flagfish Jordanella floridae. Wat. Res. 12:621-626.

Rustad, S., Christophersen, N., Seip, H.M. and P.J. Dillon. 1986. A Model for Streamwater Chemistry in a Tributary to Harp Lake, Ontario. Can. J. Fish. Aquat. Sci. (in press).

Scheider, W.A. 1984. Lake Water Budgets in Areas Affected by Smelting Practices Near Sudbury, Ontario. pp. 155-194, in Environmental Impacts of Smelters, Nriagu, J., (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Scheider, W.A. and T.G. Brydges. 1984. Whole-Lake Neutralization Experiments in Ontario: A Review. Fisheries 9:17-18.

Scheider, W.A. and P.J. Dillon. 1983. Predicting Chemical and Physical Effects of Acidic Deposition on Aquatic and Terrestrial Ecosystems - Information Needs. Proc. Symp. Monitoring and Assessment of Airborne Pollutants. Nat. Res. Council Canada. NRCC No. 20642:84-114.

Scheider, W.A., Jeffries, D.S. and P.J. Dillon. 1981. Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of Inco Ltd., in Sudbury. Atm. Environ. 15:945-956.

Scheider, W.A., Jeffries, D.S. and P.J. Dillon. 1979. Effects of Acidic Precipitation on Precambrian Freshwaters in Southern Ontario. J. Great Lakes Res. 5:45-51.

Scheider, W.A., Locke, B.A., Nicolls, A.C. and R.E. Girard. 1985. Snowpack and Streamwater Chemistry in Three Watersheds in Muskoka-Haliburton, Ontario. Proc. Can. Hydrology Symp., 10-12 June, 1984. Quebec City, Quebec (in press).

Scheider, W.A., Locke, B.A., Nicolls, A.C. and R.E. Girard. 1985. Snowpack and Streamwater Chemistry in Three Watersheds in Muskoka-Haliburton, Ontario. Proc. Can. Hydrology Symp., 10-12 June, 1984. Quebec City, Quebec (in press).

Scheider, W.A., Logan, L.A., Belore, H.S. and R.C. MacRae. 1985. Simulation of Snowmelt and Streamflow During Spring Runoff in Muskoka-Haliburton, Ontario. Proc. Can. Hydrology Symp., 10-12 June, 1984, Quebec City, Quebec (in press).

Scheider, W.A., Logan, L.A. and M.G. Goebel. 1983. A Comparison of Two Models to Predict Snowmelt in Muskoka-Haliburton, Ontario. pp. 157-168, in Proc. 40th Eastern Snow Conference, June 2-3, 1983, Toronto.

Scheider, W.A., Snyder, W.R. and B. Clark. 1979. Deposition of Nutrients and Ions by Precipitation in South-Central Ontario. Wat. Air Soil Pollut. 12:171-185.

Schiermeier, F.A. and P.K. Misra. 1983. Evaluation of Eight Linear Regional Scale Sulphur Models by the Regional Modelling Subgroup of the United States-Canada Memorandum of Intent Work Group 2. The Meteorology of Acid Deposition, Samson, P.J. (Ed.), Proceedings of an APCA Specialty Conference, pp. 330-345.

Schut, P.H., Evans, R.D. and W.A. Scheider. 1986. Variation in Trace Metal Exports from Small Canadian Shield Watersheds. Wat. Air Soil Pollut. (in press).

Seip, H.M. and P.J. Dillon. 1984. Acid Rain and Soil Chemistry. Science 225:1425-1426.

Seip, H.M., Seip, R., Dillon, P.J. and E. de Grosbois. 1985. Model of Sulphate Concentration in a Small Stream in the Harp Lake Catchment, Ontario. Can. J. Fish. Aquat. Sci. 42:927-937.

Suns, K., Curry, C. and D. Russell. 1980. Effects of Water Quality and Morphometric Parameters on Mercury Uptake by Yearling Yellow Perch. Ontario Ministry of the Environment Technical Report LTS 80-1, 16 pp.

Tung, G., Kuja, A.L. and S.N. Linzon. 1982. Histopathology of Plant Leaf Injury Caused by Simulated Acid Rain. Proceedings of Microscopical Society of Canada, Vol IX, Univ. Alberta, pp. 64-65.

Venkatram, A. 1982. Short Range Short-term Fumigation Model for the Inco Superstack. Report #SES 013/82.

Venkatram, A., Ley, B. and S.Y. Wong. 1982. A Statistical Model to Estimate Long-Term Concentrations of Pollutants Associated with Long-Range Transport and its Application to Emissions from the Sudbury Region. Report #ARB-36-81-SES.

Vet, R.J., Chan, W.H. and M.A. Lusis. 1981. An Intercomparison Study of Three Sampling Networks in Ontario - APIOS, CANSAP and GLPN. Report No. ARB-002-81-ARSP.

Wile, I., Miller, G.E., Hitchin, G.G. and N.D. Yan. 1985. Species Composition and Biomass of the Macrophyte Vegetation of One Acidified and Two Acid Sensitive Lakes in Ontario. Can. Field Nat. 99:308-312.

Wong, S.L. 1980. Algal Bioassays to Determine Toxicity of Metal Mixtures. Hydrobiol. 74:199-208.

Wright, R.F., Conroy, N., Dickson, W.T., Harriman, R., Henricksen, A. and C.L. Schofield. 1980. Acidified Lake Districts of the World: A Comparison of Water Chemistry of Lakes in Southern Norway, Southern Sweden, Southwestern Scotland, the Adirondack Mountains of New York and Southeastern Ontario. Proc. Int. Conf. on the Ecological Impact of Acid Precipitation, Sandefjord, Norway, pp. 377-379.

Yan, N.D. 1986. Empirical Prediction of Crustacean Zooplankton Biomass in Nutrient-poor Canadian Shield Lakes. Can. J. Fish. Aquat. Sci. 43:788-796.

Yan, N.D. 1983. The Effects of Changes in pH on Transparency and Thermal Regimes of Lohi Lake, Near Sudbury, Ontario. Can. J. Fish. Aquat. Sci. 40:621-626.

Yan, N.D. 1980. Acid Rain: A Progress Report. In Gulston, C.L. (Ed.). Perspectives in Natural Resources. Symposium III: Water. 6-8 November, 1980. Lindsay, Ont. pp. 95-114.

Yan, N.D. 1979. Phytoplankton of an Acidified Heavy Metal Contaminated Lake Near Sudbury, Ontario; 1973-1977. Water Air Pollut. 11:43-55.

Yan, N.D. and P.J. Dillon. 1984. Experimental Neutralization of Lakes Near Sudbury, Ontario. pp. 417-456, in Environmental Impacts of Smelters, Nriagu, J. (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D. and W. Geiling. 1985. Elevated Planktonic Rotifer Biomass in Acidified, Metal-Contaminated Lakes Near Sudbury, Ontario. Hydrobiol. 120:199-205.

Yan, N.D. and R. Girard. 1986. Delayed Recovery of Zooplankton Communities of Acidic, Metal-Contaminated Lakes Near Sudbury, Ontario Following Improvements in Water Quality. Can. J. Fish. Aquat. Sci. (in press).

Yan, N.D. and C. Lafrance. 1984. Responses of Acidic Neutralized Lakes Near Sudbury, Ontario to Nutrient Enrichment. pp. 457-521, in Environmental Impacts of Smelters, Nriagu, J. (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D., Lafrance, C.J. and G.G. Hitchin. 1982. Planktonic Fluctuations in a Fertilized, Acidic Lake: The Role of Invertebrate Predators. In Proceedings of an International Symposium on Acidic Rain and Fishery Impacts on Northeastern North America. Cornell Univ., Ithaca, N.Y., August 2-5, 1981, pp. 137-154.

Yan, N.D. and G.E. Miller. 1984. Effects of Deposition of Acids and Metals on Chemistry and Biology of Lakes Near Sudbury, Ontario. pp. 243-282, in Environmental Impacts of Smelters, Nriagu, J. (Ed.), Advances in Environmental Science Series, John Wiley and Sons, Inc.

Yan, N.D., Miller, G.E., Wile, I. and G.G. Hitchin. 1985. Richness of Aquatic Macrophyte Floras of Soft Water Lakes of Differing pH and Trace Metal Content in Ontario, Canada. Aquatic Botany 23:27-40.

Yan, N.D., Nero, R.W., Keller, W. and D.C. Lasenby. 1985. Are Chaoborus Larvae More Abundant in Acidified Lakes in Central Canada? Holartic Ecology 8:93-99.

Yan, N.D., Scheider, W.A. and P.J. Dillon. 1977. Chemical and Biological Changes in Nelson Lake, Ontario, Following Experimental Elevation of Lake pH. Wat. Pollut. Res. Can. 12:213-231.

Yan, N.D. and P. Stokes. 1978. Phytoplankton of an Acidic Lake and its Responses to Experimental Alterations of pH. Environ. Conservat. 5:93-100.

Yan, N.D. and R. Strus. 1980. Crustacean Zooplankton Communities of Acidic, Metal-Contaminated Lakes Near Sudbury, Ontario. Can. J. Fish. Aquat. Sci. 37:2282-2293.